LOSING GROUND: U.S. COMPETITIVENESS IN CRITICAL TECHNOLOGIES

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

SECOND SESSION

JANUARY 29, 2020

Serial No. 116–64

Printed for the use of the Committee on Science, Space, and Technology

Available via the World Wide Web: http://science.house.gov

U.S. GOVERNMENT PUBLISHING OFFICE
39–555PDF WASHINGTON : 2021

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HON. EDDIE BERNICE JOHNSON, Texas, *Chairwoman*

ZOE LOFGREN, California
DANIEL LIPINSKI, Illinois
SUZANNE BONAMICI, Oregon
AMI BERA, California,
Vice Chair
LIZZIE FLETCHER, Texas
HALEY STEVENS, Michigan
KENDRA HORN, Oklahoma
MIKIE SHERRILL, New Jersey
BRAD SHERMAN, California
STEVE COHEN, Tennessee
JERRY MCNERNEY, California
ED PERLMUTTER, Colorado
PAUL TONKO, New York
BILL FOSTER, Illinois
DON BEYER, Virginia
CHARLIE CRIST, Florida
SEAN CASTEN, Illinois
BEN MCADAMS, Utah
JENNIFER WEXTON, Virginia
CONOR LAMB, Pennsylvania
VACANCY

FRANK D. LUCAS, Oklahoma,
Ranking Member
MO BROOKS, Alabama
BILL POSEY, Florida
RANDY WEBER, Texas
BRIAN BABIN, Texas
ANDY BIGGS, Arizona
ROGER MARSHALL, Kansas
RALPH NORMAN, South Carolina
MICHAEL CLOUD, Texas
TROY BALDERSON, Ohio
PETE OLSON, Texas
ANTHONY GONZALEZ, Ohio
MICHAEL WALTZ, Florida
JIM BAIRD, Indiana
FRANCIS ROONEY, Florida
GREGORY F. MURPHY, North Carolina
VACANCY

C O N T E N T S

January 29, 2020

LOSING GROUND:
U.S. COMPETITIVENESS IN CRITICAL TECHNOLOGIES

WEDNESDAY, JANUARY 29, 2020

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Committee met, pursuant to notice, at 10:04 a.m., in room 2318 of the Rayburn House Office Building, Hon. Eddie Bernice Johnson [Chairwoman of the Committee] presiding.

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING CHARTER

Losing Ground: U.S. Competitiveness in Critical Technologies

Wednesday, January 29, 2020
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

On Wednesday, January 29, 2020, the Committee on Science, Space, and Technology will hold a hearing to review U.S. competitiveness in critical technologies and Federal investments in the research, development and STEM workforce that will be essential to maintaining U.S. leadership. The Committee will also examine opportunities for increased public-private partnership and the economic and national security implications of leadership – or loss of leadership – in these critical technology areas.

Witnesses

- **Dr. Diane Souvaine**, Chair, National Science Board
- **Dr. Eric Schmidt**, Founder, Schmidt Futures; Chairman, Defense Innovation Board; Chairman, National Security Commission on Artificial Intelligence
- **Dr. Chaouki Abdallah**, Executive Vice President for Research, Georgia Institute of Technology

Overarching Questions

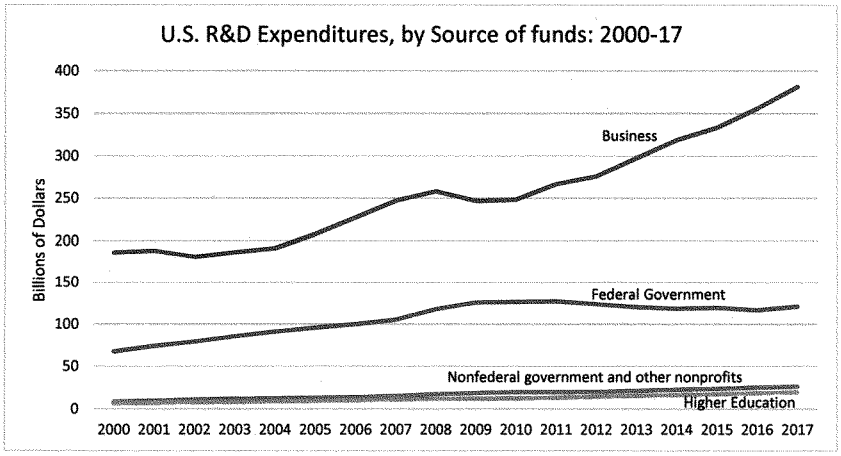
- What is the state of U.S. leadership in critical technologies such as artificial intelligence, quantum technology, synthetic biology, supercomputing, advanced materials, data storage, microelectronics, etc…? (this is not meant to be an exhaustive list)
- Why is it important for the U.S. to maintain leading capabilities in both fundamental research and technology development across these critical technology areas? What are the consequences of loss of leadership?
- What is the role of the Federal government in supporting research and development in these areas? Is the current scale and nature of investment sufficient? How can Federal agencies rethink their traditional funding models and partnership models to ensure continued leadership?

- How are universities or how can they rethink their organizational models and partnerships to situate themselves for continued leadership in research in critical technology areas? What steps are they taking to address the challenges in the U.S. STEM talent pipeline?
- How are companies or how can they rethink their approach to partnership with the Federal government and with universities in critical technology areas?

U.S. R&D Landscape

On January 15, 2020, the National Science Board (NSB) of the National Science Foundation (NSF) released its 2020 Science and Engineering Indicators report. The NSB reported that while the United States continues to lead in many key indicators, other countries are rapidly developing their science and technology capacity.

The total U.S. investment in R&D by all sectors was $548 billion in 2017. The business sector has accounted for most of the growth in total U.S. R&D over the last decade. In 2008, businesses invested $258 billion in R&D, compared to $117.6 billion by the Federal government. Today those numbers are $381 billion and $121 billion, respectively, which means the business sector now accounts for 70 percent of all U.S. R&D[1]. The remaining $46 billion comes from states, foundations, non-profit organizations, and universities' institutional funds.



[1] The most current data available from the business sector is from 2017, which is why the public vs private comparisons are from that year whereas more current data is available for the Federal government.

Federal support for R&D as a percentage of the nondefense discretionary budget has held mostly steady at 10 percent since 2000, but the total size of the nondefense discretionary budget decreased under the 2011 budget deal known as "sequestration" and is still below the level immediately preceding that deal. In constant dollars, the R&D buying power at several Federal agencies is still lower than it was prior to sequestration. The Federal government invests broadly across the R&D spectrum. However, the majority of the non-defense R&D budget, which totaled $77 billion in FY 2018, is dedicated to basic and applied research, or what the NSB is now defining collectively as "fundamental research" – original investigation that is undertaken to acquire new knowledge whether or not there is some practical objective in mind.

Since 2000, the rise in U.S. investments in R&D has largely been driven by increased investments in the private sector, which prioritizes short-term applied research and experimental development focused on improving specific products and processes. Decades ago, tech companies invested significantly more in higher-risk fundamental research. The examples most commonly cited are Bell Labs and Xerox PARC. Nine Nobel awards were given for work completed at Bell Labs, but Bell Labs began its final decline in the 2000s and was shuttered by 2008. Similarly, Xerox PARC no longer exists as it once did. Company investment in internal basic research has increased somewhat in the last few years. In 2017, businesses funded nearly 30 percent of all basic research. However, the U.S. pharmaceutical industry alone accounts for more than 50 percent of the increase in corporate sponsored basic research since the mid-2000's. Similarly, philanthropic support for research has been on the rise, but it is overwhelmingly focused on biomedical research. While some fundamental research performed by companies is published in the open literature, much of it remains proprietary.

The United States has long been home to many of the world's leading research institutions. U.S. universities perform about half of all basic research in our country and in 2018 performed a total of $79.4 billion in R&D. The share of academic R&D funded by Federal agencies declined from 57 percent in 2000 to 51 percent in 2017. Other sources of funding include institutional funds, industry, and foundations. In 2018, institutional funds constituted more than one-quarter of university research.

Federally funded research and development centers (FFRDCs), which includes the Department of Energy National Laboratories, also play an important role in our R&D enterprise, although they do not account for a large portion of the nation's total R&D performance. In 2017, FFRDCs performed less than 4 percent of all R&D. However, FFRDCs play a unique role in supporting large-scale, long-term R&D, including through the construction of major user facilities in key technology areas, including computing, biotechnology, and nanotechnology.

There are many partnerships between the government (including national labs), universities, and the private sector, and the Science Committee often explores the nature of those partnership models - what works, what can be expanded, and what new models may be viable. Such partnerships require a sustained commitment by all parties and new ways of partnering as new

challenges and opportunities arise, for example in data sharing to advance AI research for public health and other areas in the public good.

International Competition

Around the world, global R&D funding has been increasing rapidly. China alone has accounted for almost one-third of total global growth between 2000 and 2017, compared to 20 percent for the U.S and 17 percent for the European Union. In that time frame, the U.S. has shifted from making up 37 percent of global R&D share to 25.5 percent. While the data are not yet available to confirm, the NSB estimates that China's investments likely exceeded those of the United States in 2019. As a share of GDP, the U.S. is close to dropping out of the top 10 in R&D expenditures.

With respect to STEM education and the workforce pipeline, U.S. students at the K-12 level continue to rank in the middle of advanced economies on international math and science tests, and their scores have barely budged in decades. At the higher education levels, the U.S. has seen small but sustained growth in the production of STEM bachelor and doctoral degrees. China has produced more bachelor level degrees in STEM since the early 2000s and surpassed the United States in 2007 as the world's largest producer of doctoral degrees in natural sciences and engineering. While quantity does not necessarily equal quality, anecdotally at least China has been making a concerted effort to improve upon the quality of their higher education to produce graduates with the skills most valued in U.S. graduates and essential to an innovation economy – not just subject matter expertise but critical thinking, problem solving, and team work skills.

Also relevant to international competition is our ability to attract top talent from around the world. Temporary visa holders accounted for one-third of all STEM doctoral degrees awarded by U.S. universities in 2017, and half or more of all doctoral degrees awarded in engineering, mathematics, and computer sciences. The United States has long benefited from attracting the best talent from around the world. Thirty five percent of all U.S. Nobel laureates have been foreign-born scientists since the Nobel Prize was first established in the early 1900s and 44 percent of the companies in the Fortune 500 were founded by immigrant entrepreneurs or their children. However, increasingly, foreign students are either choosing to study outside of the U.S. (the EU and Australia are popular destinations), or returning to their home countries after receiving their degrees in the United States.

As the Committee has heard from many expert witnesses, it is not an either-or for universities. They want to recruit more U.S. citizens graduating with bachelor's degrees in science and engineering to pursue masters and doctoral level studies. However, in many fields, especially in information technology fields, those students can earn good salaries straight out of college and are forgoing more advanced degrees. Furthermore, our nation continues to see significant gaps in STEM achievement across racial and ethnic groups from the earliest education levels even as the nation's population becomes more diverse, and women continue to be significantly

underrepresented in key fields. Universities have a role to play in the STEM pipeline challenge and a few have shown remarkable success with targeted efforts. However, as the Committee discussed at a hearing in 2019, our nation cannot solve its STEM pipeline challenge and meet our future workforce needs without addressing the achievement and access gaps that begin at the earliest ages.

Consequences of Decreasing Federal R&D Investments

Our entire R&D enterprise is under pressure, especially the fundamental research that creates the foundation for new innovations and trains the next generation of STEM talent. University researchers spend a significant portion of their time applying for grants from programs with pay lines as low as 10 percent. As a consequence of the low pay lines, agencies and peer review panels are taking fewer risks in the grants they do fund. Many of the most talented students who otherwise might have made significant contributions to U.S. leadership in S&T see little to no future in academic research and pursue careers in the private sector, or head abroad to countries in which research funding is more readily available. In the field of artificial intelligence (AI), university faculty are leaving academia for large companies awash in data and computing resources. U.S. research infrastructure is crumbling. Many of our National Lab facilities are 50-60 years old. The same is true on many university campuses.

In areas of emerging technology that will have significant economic and security consequences, the U.S. risks falling behind. Other countries have clear national strategies and large coordinated investments in AI, biotechnology, and quantum science and engineering. The UK government has made synthetic biology a national priority since at least 2012. China has also developed an aggressive strategic roadmap in biotechnology and in 2017, China's government announced a goal of becoming a global leader in AI by 2030. The EU and China have both made significant commitments in quantum science and engineering. The U.S. only recently began to implement a national strategy for quantum science and engineering, and is still in the early stages of developing strategies for engineering biology and AI. Even with strategies in place, funding has to follow to realize the benefits and guard against the economic and security risks.

Many recent reports and expert groups lay out these risks in detail and make recommendations about what is required to maintain U.S. leadership:

Council on Foreign Relations, "Innovation and National Security: Keeping our Edge"

National Academies of Science, Engineering and Medicine, "Safeguarding the Bioeconomy"

National Security Commission on Artificial Intelligence, Interim Report to Congress

Defense Innovation Board Recommendations

National Academies of Science, Engineering, and Medicine, "Science and Innovation Leadership for the 21st Century: Challenges and Strategic Implications for the United States" (ongoing)

Chairwoman JOHNSON. The hearing will come to order. Without objection, the Chair is authorized to declare a recess at any time.

Good morning to all. This hearing on United States competitiveness in critical technologies is our topic. And welcome to our distinguished panel of witnesses.

United States leadership in science and technology has long given U.S. companies a competitive advantage, which in turn has led to job creation and increased standards of living for all Americans. It has also bolstered our national defense.

However, as recent reports have underscored, the United States has already begun to face the consequences of our inability to make strategic and sustained long-term investments in our science and technology enterprise. For too long, we have coasted on the vision and political will that our leaders had in the 1950s, when they enacted the *National Defense Education Act*, and other seminal laws that invested in our Nation's talent and built the foundations for U.S. leadership in science and technology.

We have risen to the challenge a few times since then, for example, the doubling of the NIH (National Institutes of Health) budget and the initiatives in the *America COMPETES Act*, including the creation of ARPA-E (Advanced Research Projects Agency-Energy). However, in the last 15 years, the non-defense research and development (R&D) budget has stagnated. We have been lamenting our domestic STEM (science, technology, engineering, and mathematics) pipeline challenge for decades, yet we have not made much progress.

In the meantime, other countries have implemented strategies and invested significantly in their science and technology capacity. As a result, they are now retaining and attracting talent that once came to the United States to study, conduct research, and build companies here. Those are just a few of the indicators that should serve as a warning to all of us that we are losing ground.

The economic and national security risk of loss of leadership are particularly high in some science and technology fields. If we do not lead, we will be poorly positioned to help set global norms and standards for the responsible development and application of emerging technologies such as artificial intelligence (AI) and biotechnology. Even when our best efforts to set norms are not enough, science and technology (S&T) leadership will enable us to develop strong defensive capabilities to protect the American people against those who wish us harm.

I do not want to cause any confusion about where I stand. I remain as firmly committed as ever to our investments across all fields of science and engineering, as well as the humanities. Those who study ethics and philosophy and other aspects of human society will be needed alongside those who study bytes and microbes. Without this scholarly partnership, the United States will not have the tools to lead responsibly at home or abroad.

The other partnership that remains essential is that between the public and private sectors. The private sector has been increasing its investments in research and development even as the public sector has fallen back. However, the objectives and the constraints are very different for each sector. Joined together in effective part-

nership, on the other hand, the two sectors can leverage each other's strengths and resources to advance shared goals.

Our Nation has accomplished great things when we have put our minds to it. We sent a man to the moon, invented GPS and the internet, and developed the entire field of synthetic biology. We have what it takes to lead. The question is, will we do what it takes?

As we embark on another busy year in this Committee, I look forward to today's testimony and discussion that will help us frame both the challenges and opportunities ahead for American leadership in science and technology.

[The prepared statement of Chairwoman Johnson follows:]

Good morning and welcome to this hearing on United States Competitiveness in Critical Technologies. And welcome to our distinguished panel of witnesses.

United States leadership in science and technology has long given U.S. companies a competitive advantage, which in turn has led to job creation and an increased standard of living for all Americans. It has also bolstered our national defense. However, as recent reports have underscored, the United States has already begun to face the consequences of our inability to make strategic and sustained long-term investments in our science and technology enterprise. For too long we have coasted on the vision and political will that our leaders had in the 1950s, when they enacted the *National Defense Education Act* and other seminal laws that invested in our nation's talent and built the foundations for U.S. leadership in science and technology.

We have risen to the challenge a few times since then, for example in the doubling of the NIH budget and the initiatives in the *America COMPETES Act*, including the creation of ARPA-E. However, in the last 15 years, the nondefense research and development budget has stagnated. We have been lamenting our domestic STEM pipeline challenge for decades, yet we have not made much progress. In the meantime, other countries have implemented strategies and invested significantly in their science and technology capacity. As a result, they are now retaining and attracting talent that once came to the United States to study, conduct research, and build companies here. Those are just a few of the indicators that should serve as a warning to all of us that we are losing ground.

The economic and national security risks of loss of leadership are particularly high in some science and technology fields. If we do not lead, we will be poorly positioned to help set global norms and standards for the responsible development and application of emerging technologies such as artificial intelligence and biotechnology. Even when our best efforts to set norms are not enough, science and technology leadership will enable us to develop strong defensive capabilities to protect the American people against those who wish us harm.

I do not want to cause any confusion about where I stand. I remain as firmly committed as ever to our investments across all fields of science and engineering as well as the humanities. Those who study ethics and philosophy and other aspects of human society will be needed alongside those who study bytes and microbes. Without this scholarly partnership, the United States will not have the tools to lead responsibly at home or abroad.

The other partnership that remains essential is that between the public and private sectors. The private sector has been increasing its investments in research and development even as the public sector has fallen back. However, the objectives and the constraints are very different for each sector. Joined together in effective partnership, on the other hand, the two sectors can leverage each other's strengths and resources to advance shared goals.

Our nation has accomplished great things when we have put our minds to it. We sent a man to the moon, invented GPS and the internet, and developed the entire field of synthetic biology. We have what it takes to lead. The question is, will we do what it takes?

As we embark on another busy year in this Committee, I look forward to today's testimony and discussion that will help us frame both the challenges and opportunities ahead for American leadership in science and technology.

Chairwoman JOHNSON. I now recognize Mr. Lucas, our Ranking Member, for his opening statement.

Mr. LUCAS. Thank you, Chairwoman Johnson, for holding this important hearing on U.S. competitiveness in critical technologies.

American superiority in science and technology is fundamental to our economic competitiveness, our national security, and our way of life. But the U.S. is facing two fundamental challenges to our competitiveness and growth as a Nation. First, foreign countries, especially China, are threatening to outpace us in scientific research and development. Second, we must respond to the changing climate and develop next-generation technologies to understand it, address it, and mitigate it.

To meet these two generational challenges, we must accelerate our investments in basic research, as well as invest in the tools and infrastructure needed to support that research. That's why yesterday I introduced the *Securing American Leadership in Science and Technology Act*. I'm proud to be joined by many of my Republican colleagues on the Science Committee on this bill, which creates a long-term strategy for growing our Nation's investment in basic research and research infrastructure, while cutting red tape to improve taxpayers' returns on investment.

The bill directs the development of a National Science and Technology Strategy for the United States and a quadrennial review process. This will provide a more strategic, whole-of-government effort for setting national priorities and improving coordination between Federal agencies.

The bill prioritizes investment in Federal basic research. It authorizes a doubling of basic research funding over the next 10 years at the Department of Energy (DOE), the National Science Foundation (NSF), the National Institute of Standards and Technology (NIST), and the National Oceanic and Atmospheric Administration (NOAA).

The bill also prioritizes research infrastructure, from light sources to supercomputers. If we want to do big things and compete for the best scientists and companies in the world to work here in the U.S., we need world-class facilities.

The bill promotes the development of an American STEM-capable workforce. To support the industries of the future, we need workers with STEM skills at all levels, from the skilled technical workforce to the Ph.D.-level scientists.

Finally, the bill includes regulatory reform to improve the effectiveness of taxpayer investments in R&D. The bill updates technology transfer laws to get research out of the lab and into the private industry for development, and makes it easier for private industry to collaborate with the Federal Government on research.

I recognize that we are the minority party and that we do not get to set the agenda. But I believe we have many shared priorities. I believe this legislative package will start a bipartisan conversation about what we need to do to ensure America's lead in the technological revolution of the 21st Century.

China has made it an explicit goal to surpass the U.S. in critical technologies. Their "Made in China 2025" initiative is a bold plan, which outlines their intent to become global leaders in areas like quantum information science, advanced robotics, aerospace, and biotechnology. China is making real investments in R&D, increasing government-funded R&D by 56 percent between 2011 and 2016.

At the same time, U.S. investment in basic civilian research has stagnated, falling by 12 percent in absolute terms. As we will hear

today, there are indications that China may have already surpassed the U.S. in total research investment this year. China is also pushing a strategy of promoting foreign acquisitions, forced technology transfer agreements, and, in many cases, commercial cyber-espionage to gain cutting-edge technologies and know-how.

We must protect our Nation's research and intellectual property. The Trump Administration has taken good steps toward protecting American IP (intellectual property) from Chinese aggression. But we must do more to protect sensitive American research, while maintaining the spirit of open science that has fueled generations of discoveries.

As any good football coach will tell you, the best defense is a good offense. American industry is the driver of investment in R&D spending in this country, accounting for 70 percent of U.S. R&D. But those investments are fueled by the ideas that come out of government-funded basic research, the type of research that industry doesn't undertake because it's too risky and it's too early-stage. Since World War II, the successful partnership between government, academia and industry, has made our research enterprise the envy of the world. It's time to renew that enterprise.

Americans are pioneers, and this spirit has always driven our support for science. But I believe we need to collectively do a better job of providing a vision for why science matters to all Americans. I look forward to hearing from our distinguished panel of witnesses about how we can work together to meet this challenge and ensure America continues to lead in science and technology.

And with that, I yield back, Madam Chair.

[The prepared statement of Mr. Lucas follows:]

Thank you, Chairwoman Johnson for holding this important hearing on U.S. Competitiveness in Critical Technologies.

American superiority in science and technology is foundational to our economic competitiveness, our national security, and our way of life. But the U.S. is facing two fundamental challenges to our competitiveness and growth as a nation.

First, foreign countries, especially China, are threatening to outpace us in scientific research and development. Second, we must respond to a changing climate and develop next-generation technologies to understand it, address it, and mitigate it.

To meet these two generational challenges, we must accelerate our investments in basic research, as well as invest in the tools and infrastructure needed to support that research. That's why yesterday I introduced the *Securing American Leadership in Science and Technology Act*.

I'm proud to be joined by many of my Republican colleagues on the Science Committee on this bill, which creates a long-term strategy for growing our nation's investment in basic research and research infrastructure, while cutting red tape to improve the taxpayers' return on investment. The bill directs the development of a National Science and Technology Strategy for the United States and a quadrennial review process. This will provide a more strategic, whole-of government effort, for setting national priorities and improving coordination between federal agencies.

The bill prioritizes investment in federal basic research. It authorizes a doubling of basic research funding over the next 10 years at the Department of Energy, the National Science Foundation, the National Institute of Standards and Technology, and the National Oceanic and Atmospheric Administration. The bill also prioritizes research infrastructure. From light sources, to supercomputers—if we want to do big things and compete for the best scientists and companies in the world to work here in the U.S., we need world-class facilities.

The bill promotes the development of an American STEM-capable workforce. To support the industries of the future, we need workers with STEM skills at all levels—from the skilled technical workforce to Ph.D. level scientists.

Finally, the bill includes regulatory reform to improve the effectiveness of taxpayer investments in R&D. The bill updates technology transfer laws to get re-

search out of the lab and into private industry for development, and makes it easier for private industry to collaborate with the federal government on research.

I recognize that we are the minority party and that we do not get to set the agenda. But I believe we have many shared priorities and I hope this legislative package will start a bipartisan conversation about what we need to do to ensure America lead's the technological revolution of the 21st Century.

China has made it an explicit goal to surpass the U.S. in critical technologies. Their "Made in China 2025" initiative is a bold plan, which outlines their intent to become the global leader in areas like quantum information science, advanced robotics, aerospace and biotechnology. China is making real investments in R&D-increasing government-funded R&D by 56 percent between 2011 and 2016. At the same time, U.S. investment in basic civilian research has stagnated, falling by 12 percent in absolute terms. As we will hear today, there are indications that China may have already surpassed the U.S. total research investment this year. China is also pushing a strategy of promoting foreign acquisitions, forced technology transfer agreements, and, in many cases, commercial cyber-espionage to gain cutting-edge technologies and know-how.

We must protect our nation's research and intellectual property. The Trump Administration has taken good steps towards protecting American IP from Chinese aggression. But we must do more to protect sensitive American research, while maintaining the spirit of open science that has fueled generations of discoveries. As any good football coach will tell you, the best defense is a good offense.

American industry is the driver of investment in R&D spending in our country, accounting for 70% of U.S. R&D. But those investments are fueled by the ideas that come out of government-funded basic research, the type of research that industry doesn't undertake because it's too risky and too early-stage. Since World War II, the successful partnership between government, academia and industry, has made our research enterprise the envy of the world. It's time to renew that enterprise.

Americans are pioneers and this spirit has always driven our support for science. But I believe we need to collectively do a better job of providing a vision for why science matters to all Americans. I look forward to hearing from our distinguished panel of witnesses about how we can work together to meet this challenge and ensure America continues to lead in science and technology.

Chairwoman JOHNSON. Thank you, Mr. Lucas.

At this time I'd like to introduce our witnesses. Our first witness is Dr. Diane Souvaine. Dr. Souvaine is currently serving as Chair of the National Science Board (NSB), a position she has held since 2018. From 2016 to 2018 she served as Vice Chair. She was first appointed to the Board in 2008 and reappointed in 2014. She's also a Professor of computer science and Adjunct Professor of mathematics at Tufts University, where she has been a member of the faculty since 1998. During her tenure at Tufts, she has served in several leadership positions, including Vice Provost for Research, Senior Advisor to the Provost, and Chair of the Department of Computer Science.

Our next witness is Dr. Eric Schmidt. Dr. Schmidt is the founder of Schmidt Futures and also Technical Advisor to Alphabet Inc., where he advises leaders on technology, business, and policy issues. Previously, he was Executive Chairman of Alphabet from 2015 to 2018 and of Google from 2011 to 2015, where he also served as CEO from 2001 to 2011. Dr. Schmidt became Chairman of the Department of Defense's (DOD's) Innovation Board in 2016 and was awarded the Department of Defense Medal for Distinguished Public Service in 2017. He is also Chairman of the U.S. National Security Commission on Artificial Intelligence and was a member of the President's Council of Advisors on Science from 2009 to 2017.

Our third witness is Dr. Chaouki Abdallah. Dr. Abdallah is Executive Vice President for Research at the Georgia Institute of Technology, that is Georgia Tech, a position he has held since 2018. In this position he provides overall leadership for the research, eco-

nomic development, and related support units within Georgia Tech and serves on the President's Executive Leadership Team. Dr. Abdallah also serves on the Executive Committee for the Association of Public and Land Grant Universities and the Government-University-Industry Research Roundtable. Prior to his position at Georgia Tech, he spent his career at the University of New Mexico, including as Chair of the Electrical and Computer Engineering Department, Provost, and then briefly as President from January 2017 to February 2018.

As our witnesses should know, each of you will have 5 minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When all of you have completed your spoken testimony, we will begin questions with each member having 5 minutes to question the panel. And so we will start now with our first witness Dr. Souvaine.

TESTIMONY OF DR. DIANE SOUVAINE,
CHAIR, NATIONAL SCIENCE BOARD

Dr. SOUVAINE. Thank you. Chairwoman Johnson, Ranking Member Lucas, and Members of the Committee, thank you for the opportunity to speak with you today as Chair of the National Science Board.

For 70 years, science and engineering have driven our economic growth, underpinned our national security, and transformed nearly every aspect of our lives. This was no accident. Congress' sustained bipartisan commitment to basic research has played a key role in creating a knowledge ecosystem in which academia, government, and the private sector partner to drive innovation.

Science and Engineering Indicators 2020, which the Board released 2 weeks ago, shows that S&E (science and engineering) is now truly a worldwide enterprise, connected, complex, and interdependent with more players and opportunities and humanity's collective knowledge growing exponentially. While science is the endless frontier, we're not the only explorers. Staying at the forefront of S&E is essential for our economy and our security. As other countries have invested in their own research enterprises, our share of global discovery and innovation has declined and will likely continue to decline. We are no longer the uncontested leader in S&E, and we must adapt to changes in the world and in our country.

In my written testimony I described the growth of S&E investments around the world and the accompanying increase in international competition and collaboration. I also talk about the importance of foreign talent and the urgent need to build and diversify our domestic STEM workforce. I also suggest that we must recognize that the private sector now funds more fundamental R&D than the Federal Government does, and it is key to our S&E ecosystem's response to rising competition.

In thinking about our strategy, I would highlight two areas. First, we need to compete with both intangibles and money. In recent years, both the private sector and Congress have responded to our peers worldwide with increased investment, including NSF. And for our part we're grateful to Congress for their wisdom. Only the Federal Government can make strategic long-term commit-

ments to creating the new knowledge that is the seed corn for the entire U.S. S&E enterprise.

Despite these increases, the Board believes that China has already surpassed us in R&D investments. And relatively slow increases in public investment has a cost. Between 2000 and 2017, while global R&D investments tripled, NSF's funding rate fell from 33 percent to 21 percent, leaving billions in outstanding merit-reviewed ideas unfunded.

AI and quantum computing are now critical technologies in part because NSF supported early-stage research years ago. As NSF looks to the next big thing, are we already leaving another Google, LIGO (Laser Interferometer Gravitational-Wave Observatory), or Kevlar on the cutting room floor? As you consider legislation, I encourage you to ask, what do our agencies need to accomplish their missions, and what does our country need to retain preeminence in S&E?

Second, to produce results, R&D investments must be coupled with a highly skilled STEM-capable workforce from skilled technical workers to PhDs. We must move aggressively to grow and diversify our domestic STEM workforce. At the same time we must acknowledge our near-term reliance on foreign-born talent. This dependence is particularly acute in computer science, math, and engineering—fields that are vital to many critical technologies.

Amid a new global bidding war for S&E talent, we must welcome international students and workers. We need to also make our S&E enterprise a magnet for curious creative Americans from all backgrounds and from every State who want to explore, solve problems, and make the world a better place. We must build a more inclusive S&E ecosystem, upgrade K–12 STEM education, and ensure robust pathways into S&E jobs. We must remember that education is a public good and that public universities and colleges have a special role to play in bringing the innovation economy to every State. Our message must be unified and clear: STEM is for all Americans. Just as illiteracy cannot be considered a virtue, it can no longer be socially acceptable to be bad at math.

To conclude, this is our ask: Be fearless. Let's not merely react to anxieties from global competition, concern about security threats, or angst about constrained budgets. Instead, let's act now before lagging indicators show that it's too late.

Let's recommit to the partnerships among government, universities, and the private sector that have driven our success, embracing the obligation to turn our Nation's lead in basic research into innovations.

Let's embrace America's identity as the land of opportunity and remember the can-do attitude that defines our people.

Let's unleash the strength of our values: A spirit of exploration, of wonder, of discovery, coupled with a willingness to take risks and an emphasis on freedom and individual creativity to ensure America's continued preeminence in research and innovation in the 21st century. Because the best way to lead the future is to invent it.

I thank you for your time and look forward to your questions.

[The prepared statement of Dr. Souvaine follows:]

Testimony of
Diane Souvaine, PhD
Chair
National Science Board
National Science Foundation

Before the
Committee on Science, Space, & Technology
U.S. House of Representatives

January 29, 2020

"Losing Ground: U.S. Competitiveness in Critical Technologies"

Since World War II, advancements in science and technology have driven much of our economic growth, underpinned our national security, and transformed nearly every aspect of Americans' daily lives. New technologies built on federally funded discovery research have led to new businesses, revolutionized health care, and created the mobile, digital world.

Our preeminence has not happened by chance. Sustained, bipartisan commitment to investing in basic research has played a key role in establishing and maintaining our knowledge ecosystem and the innovation-driving partnership among academia, government, and the private sector. As we think about what our country needs to compete in the 21st century global economy, we must renew our commitment to strengthen this key component of our national infrastructure and ensure that we are not technologically surprised in critical technologies like quantum computing and artificial intelligence. Collectively, we must do this because the world has changed, and our country has changed – and while science is the endless frontier, we are **not** the only explorers.

The data in *Science & Engineering Indicators 2020*, released two weeks ago by the National Science Board (NSB), illustrate this new global context.[1] Science and engineering (S&E) is now a truly worldwide enterprise, more connected and complex, with more players, more opportunities everywhere, and humanity's collective knowledge growing exponentially. This dynamic multipolar landscape is characterized by interdependence as well as competition. While future American preeminence is not assured, we should react with excitement, not fear to this new world. We are well positioned to compete, collaborate, and thrive.

Freewheeling creativity, an entrepreneurial ethos, and the exchange of talent and ideas across sectors are hallmarks of America's S&E enterprise. A wonderful example can be found in the story of last year's Nobel Prize in Chemistry. After arriving in the U.S. to take up a postdoctoral fellowship at Stanford University, Dr. Stanley Whittingham's research in basic chemistry focused on the phenomenon of intercalation in solid materials. His work led him to propose that these materials could be used as electrodes in powerful batteries.

[1] *Science & Engineering Indicators* is prepared under the guidance of the NSB by the National Center for Science and Engineering Statistics, a federal statistical agency within the National Science Foundation.

Using superconducting materials and lithium, he invented the rechargeable lithium battery while working as a research scientist at Exxon, which was interested in developing alternatives to gasoline-powered vehicles during the oil crisis of the 1970s. Dr. Whittingham was granted the original patent on the concept for this type of battery, and his foundational research, developed further by his co-laureates, ultimately led to the invention of rechargeable lithium-ion batteries – which now power everything from cars to the mobile phones we hold in our hands.

This story encapsulates many of the strengths of our S&E ecosystem – support for basic science from both the federal government and the private sector, welcoming of talent from around the globe, and giving the best minds the freedom to explore new frontiers and see where discovery leads them. This freedom of inquiry enabled by federal support for basic research through NSF and other government agencies has led to surprising new knowledge that has advanced our nation in unexpected, unpredictable ways. As President Ronald Reagan noted, "The remarkable thing is that although basic research does not begin with a particular practical goal, when you look at the results over the years, it ends up being one of the most practical things government does." Over the past seventy years, NSF has supported 242 Nobel Prize winners, including Dr. Whittingham, who has received thirty NSF awards in his illustrious career. History has shown that the risks taken by the federal government to fund such creative researchers and bold ideas has paid off time and time again, with all sectors of our knowledge ecosystem partnering to drive innovation.

U.S. Research and Development in the Global Context

Since 2000, global research and development (R&D) investments have tripled, reflecting increased competition in knowledge-intensive industries and recognition of the crucial role R&D plays in addressing global health, security, and environmental challenges. *Indicators 2020* confirms a trend that NSB has observed for several years: while the U.S. remains a leading player, other countries have seen the benefits of investing in research and education and are following our example.[2] The world of R&D performance, historically centered around the U.S., Western Europe, and Japan, has been shifting toward East and Southeast Asia.

U.S. spending on R&D grew modestly between 2000 and 2017, averaging 4.3% growth annually, driven mainly by the business sector. Business has been the largest funder of total R&D in the U.S. since the 1980s (currently 70% of the total). Even with this growth, since the beginning of this century our global share of R&D has declined from 37% to 25%. This is a pattern that we see repeatedly in *Indicators 2020* – that while the U.S. S&E enterprise is growing in absolute terms, the global S&E enterprise is growing faster and consequently the U.S. share of discovery is dropping.

While China is not the only story, its dramatic annual rate of R&D investment sets the country on a path to soon becoming the world's largest R&D performer.[3] If we look at the changes in global R&D expenditures since 2000, China has accounted for almost one-third of the total global growth. It is worth noting that the majority of the rise of China's R&D expenditures have been in experimental development.

In 2018, the NSB issued a statement noting that China would likely surpass the U.S. in total R&D expenditures by the end of 2018.[4] The most recent data show that there was higher than projected growth in U.S. R&D, primarily due to increased business expenditures in experimental development. In fact, in 2017 the U.S. spent more on R&D than any other country: $548 billion. Even so, the trend lines in Figure 1 suggest that in 2019 China may have surpassed the U.S. in **total** R&D expenditures.

---

[2] National Science Board (2020). "Research and Development: U.S. Trends and International Comparisons," *Science & Engineering Indicators 2020*. NSB-2020-3.
[3] Performer is defined in the OECD Frascati manual, pg. 377.
[4] National Science Board (2018). "Statement on Global R&D Investments." NSB-2018-9.

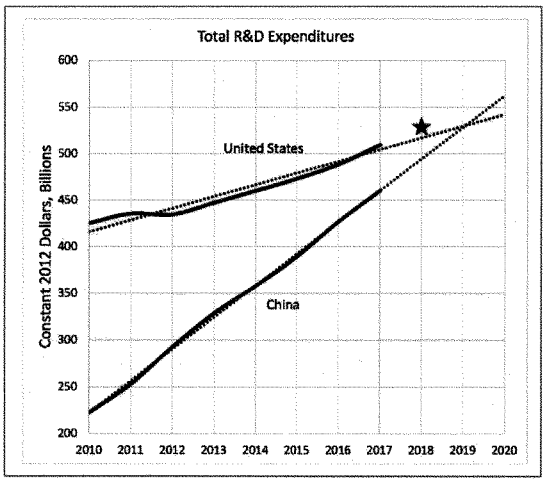


Figure 1: Gross Expenditures on R&D for the U.S. and China

Amid this dramatic growth in China's R&D investment, it is crucial to note that the U.S. maintains a significant advantage in *basic* research – the seed corn for our entire S&E enterprise. In 2017, the U.S. invested $92 billion in basic research; China came in a distant second, investing $27 billion.

While the lion's share of business investment continues to be on the development side, the business sector is also now the largest funder of basic and applied research at 43% (compared to the 38% share from the federal government). Industry's commitment to basic and applied research is a strength for our S&E ecosystem, which is built on partnerships across sectors. It is worth noting that business basic and applied research is concentrated in a few areas, with much of their investment occurring in pharmaceuticals, transportation, and computing. Federal basic and applied research investments complement and underpin these private sector investments. Furthermore, only the federal government can make a strategic, long-term commitment to creating new knowledge across *all* fields of science and engineering – including areas that cannot be anticipated to lead to new or improved technologies, goods, or services – and support risks that are difficult for the private sector to undertake.

We Must Adapt

American preeminence in S&E has shaped our way of life for seven decades. As we look to the future, one thing we can be sure of is that scientific discoveries and inventions will continue to open new, unexpected frontiers. The U.S. is no longer the uncontested world leader in S&E, and so we cannot be complacent in the face of these changes. **We must adapt.**

Why is U.S. leadership in S&E so important? From quantum computing to artificial intelligence (AI) to the data revolution, scientific advancements come with both opportunities and risks. To mitigate those risks in a competitive world, it is essential that we stay at the forefront of science and cutting-edge research. The U.S. will not regain its share dominance, so we must be proactive, and ask - what do we need to do *now* to *continue* to be a global S&E leader in the coming decades?

Continue robust federal funding for basic research

> *"There is...the risk a society runs when it falls into the habit of responding to long-term risks with short-term solutions.... It is the ceding of technical and scientific leadership to China. It is the innovation that never occurs, and the knowledge that is never created, because you have ceased to lay the groundwork for it. It is what you have never learned that might have saved you."*
>
> *– Michael Lewis*

We know that China and other nations are actively working to lead in critical technologies that hold enormous promise for revolutionizing our world. The White House and Congress are stepping up to meet this challenge, with increased focus and investment in key areas of S&E research and development. With sustained federal investments, the Administration is advancing U.S. leadership in Industries of the Future: AI, quantum information sciences, 5G/advanced communications, biotechnology, and advanced manufacturing R&D. The NSB applauds these efforts – it is wonderful to see the influx of national attention and both public and private sector investment in these areas – and believes that NSF will continue to play an essential role in addressing fundamental questions in these fields as we go forward.

Many of these research areas are now ripe for an explosion of public and private investment in part *because* NSF supported early-stage research in these fields years ago. Public funding of basic research is a sustained commitment over a long time horizon, and a competitive advantage for the U.S. The past has shown that investment in basic research now will give us the keys to meeting the security, health, and economic challenges of the future – challenges we know will arise but whose nature we cannot predict. So, in addition to furthering the development of cutting-edge fields that are widely recognized as important to our nation's competitiveness, at its core, a central mission of NSF is to ask: what is the *next* big thing? NSF is the only federal agency that supports basic research in and among *all* areas of science and engineering. Identifying the most promising, creative ideas of America's research community, through rigorous peer review, is what will lead to the transformative discoveries that will shape our world decades from now.

In anticipating what's next for our nation's S&E ecosystem, it is also important to recognize the interdependent roles in our current one. A basic research agency like NSF has significant differences in scope and time horizons from private business and mission agencies. Partnerships among and between the federal government and universities, between universities and the private sector, and those with non-profits have led to a system in which the federal government supports 42% of basic research, including the high risk, long-term basic research that the private sector is not positioned to undertake. Universities perform nearly half of U.S. basic research, with industry funding and performing a majority of applied and developmental work. These investments set the table for directed research of the mission agencies and the private sector. For example, it is worth noting that the percentage of U.S. patents *derived from government-funded research* is near an all-time high.[5]

We need to formulate a strategy for federal investment in basic research that considers current national needs and competitive opportunities *and* lays the groundwork for future discoveries. An effective plan, built on a holistic evaluation of our national research portfolio – including the private sector – and a recognition that the best ideas come from researchers, would help us match our strategic priorities with our investments. Our vision of the future cannot be limited to competing with other countries in current areas of global importance. To pursue the next "big thing," our brightest minds will need the time, space, and resources to scout the path to new frontiers.

Yet although NSF's funding has grown in real terms, NSF's funding rate for research grants has fallen from 33% (total submitted proposals: 29,508) in 2000 to 21% (total submitted proposals: 40,678) in 2017, leaving

[5] Fleming et al. (2019). "Government-funded research increasingly fuels innovation," *Science*, 364(6446) 1139-1141.

$1.6 billion in great proposals unfunded.[6] When that happens, a researcher may leave the country to pursue his/her work, submit the proposal elsewhere, perhaps to one of our international competitors, or the idea may die in the intellectual dustbin of unfulfilled promise, as the researcher drops the line of inquiry, or – worse – leaves S&E for another career.

To attract, develop, and retain S&E talent, and to be competitive in developing critical technologies of today while also searching for the breakthroughs of tomorrow, the nation needs **robust, sustained** federal funding for basic research. Overall, the federal government's share of R&D funding has declined since 2000; government spending on R&D now is 0.7% of GDP, as compared to 1.69% in 1960. We thank you for the strong, bipartisan support shown for NSF in FY 2019 and FY 2020. But this upward turn is not enough to keep up with the accelerating pace of global research and the new global bidding war for the world's best S&E talent.

Be a magnet for talent

> *"We've arranged a civilization in which most crucial elements – transportation, communications, and all other industries; agriculture, medicine, education, entertainment and protecting the environment; and even the key democratic institution of voting – profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology."*
>
> *– Carl Sagan, "With Science on Our Side," The Washington Post, January 9, 1994*

To produce results, R&D investments must be coupled with building a highly skilled, STEM-capable workforce, including everyone from skilled technical workers to PhDs. Demand for people with S&E skills keeps growing, driven by international opportunities and competition, and by disproportionate growth in the number of jobs at all levels that require STEM skills, including lines of work that historically did not require S&E knowledge. As of 2017, nearly 21 million U.S. workers with at least a four-year degree say that their job requires a "bachelor's level" of STEM expertise. The majority of these workers (71%) are employed by the business sector, the cornerstone of our nation's global economic competitiveness. Industry and the Federal government report that they are unable to find enough workers at all levels with enough STEM knowledge and skills. This situation will only become more urgent: by 2026, S&E jobs are predicted to grow by 13% compared with 7% growth in the overall workforce.

The U.S. has long relied on foreign-born talent to help meet its S&E job needs at the bachelor's and advanced degree levels, and this dependence has increased significantly over the last 25 years. As of 2017, over 40% of our doctoral-level S&E workforce was foreign-born, and in most S&E occupations, the higher the degree level, the greater the proportion of the workforce that is foreign-born.[7] In computer sciences, mathematics, and engineering – fields that are crucial to many of the Industries of the Future – nearly 60% of PhD holders in the U.S. workforce are foreign-born (Figure 2), and over 50% of the U.S. doctoral degrees awarded in these fields since 2010 were earned by foreign-born students.

At the same time, the U.S. share of internationally mobile students has declined slightly, even as the number of these students has risen dramatically worldwide. Between 2015 and 2017, the number of foreign students enrolled in graduate study in natural science or engineering programs in the U.S. decreased by 7%.[8] Since 2003, there have also been notable declines in the "stay rates" for the two largest source countries for

---

[6] Report to the National Science Board on NSF's Merit Review Process, Fiscal Year 2017, NSB-2019-15.
[7] National Science Board (2019). "Science & Engineering Labor Force," *Science & Engineering Indicators 2020*. NSB-2019-8.
[8] National Science Board (2019). "Higher Education in Science & Engineering," *Science & Engineering Indicators 2020*. NSB-2019-7.

international students – China and India – as more of those students leave the U.S. within five years of earning their degree.

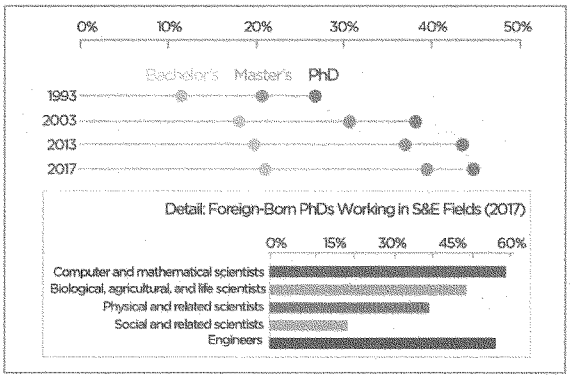


Figure 2: Percent of U.S. S&E Workers who are Foreign-Born

More countries than ever are now competing for the best minds, and these individuals have choices today that did not exist as recently as 20 years ago in selecting a place to study, perform research, and innovate. Some of our competitors have adapted their immigration policies to make it easier for highly skilled S&E workers and STEM students to work or study in their countries. Amid this global bidding war for talent, we can no longer take it for granted that the U.S. will remain the destination of choice. Even under the most optimistic scenarios for domestic talent development, in the near and medium term the U.S. will remain reliant on foreign talent. As such, we must ensure that international students and workers who choose to come here feel welcome and secure. We must also provide a research environment that is a magnet for *all* individuals who want to pursue S&E education and careers – both domestic *and* foreign.

In this new global context, relying on an ever-increasing influx of individuals from other countries is not a sustainable long-term strategy for maintaining a thriving, competitive U.S. S&E enterprise. Our ability to discover, invent, and innovate relies on our ability to develop, attract, and retain our *domestic* S&E talent while continuing to welcome researchers from around the world. We must ensure that our S&E enterprise is a magnet for curious, creative, ambitious Americans from all backgrounds who want to explore, to solve problems, and to make the world a better place. And we must recognize that STEM is no longer just for scientists and engineers, and adapt accordingly.

The NSF Act directed the agency to "strengthen research and education in the sciences and engineering… throughout the United States, and to avoid undue concentration of such research and education." The Board strongly agrees with this charge – no zip code or demographic should be unable to participate in the S&E economy, and we need *all* of our domestic talent if we want to compete in this era of globalized discovery. It is the responsibility of *all* of us to ensure that our domestic S&E talent is nurtured at every educational level, among all demographic groups, and in every region of the country. Congress, the Administration, government at all levels, business leaders, educators, and other decision-makers must work together to build a more inclusive STEM enterprise, upgrade our education system to prepare students with the skills they will need, and ensure robust pathways at all educational levels into S&E jobs. For the U.S. S&E enterprise truly to flourish, it must reflect the nation's diversity. Our message must be unified and clear: STEM is for **all**

Americans. And just as illiteracy is not considered a virtue, it can no longer be acceptable to be "bad at math."

Efforts to develop our domestic talent must begin at the K-12 level. Despite the emphasis on STEM education in recent years, U.S. students consistently rank below students in many other nations in science and math. Based on test scores, U.S. science and mathematics education at the elementary and secondary level is mediocre relative to other nations, and U.S. student performance has been stagnant over the last decade.[9] To improve student performance, we must redouble our efforts to ensure that all students develop STEM skills and adapt our educational system to teach the skills of today and the future, including critical thinking, problem-solving, creativity, and digital literacy. This undertaking will require coordination and renewed investment by many entities including government at all levels, public and private educational institutions, and industry, as well as a concerted effort to bring the best research-based STEM pedagogy and practices for diversity and inclusion to the classroom. For its part, the NSF invests in all levels of STEM education research, from pre-K-12 through graduate education, and has placed an emphasis on broadening participation in the sciences through programs such as its INCLUDES Big Idea.

Post-secondary STEM education and workforce development efforts must likewise welcome and serve individuals across all geographic locations and economic, racial, and ethnic backgrounds. The racial and ethnic composition of S&E degree recipients has changed over time, reflecting population changes and increasing rates of higher education attainment by members of underrepresented minority groups. Turning to the S&E workforce, the data show that the numbers of women and underrepresented minorities – blacks, Hispanics, and American Indians and Alaska Natives – have increased. Since 1993, the numbers of underrepresented minorities with their highest degree in S&E collectively increased nearly four-fold. The number of women in S&E jobs or who hold a bachelor's degree or higher in S&E has doubled since 1995. However, these increases were outpaced both by the rapid growth of S&E jobs as well as minority population growth, so that women and minorities remain underrepresented relative to their proportions in the U.S. population.

As the NSB underscored in our recent report, *The Skilled Technical Workforce: Crafting America's Science and Engineering Enterprise*, to meet the need for a STEM-capable workforce that can fuel our competitiveness, we must place emphasis on skills as well as degrees and embrace a pathways model to post-secondary STEM education and workforce development.[10] We need to remember that education is a public good, and that public universities and colleges, including community colleges, have a special role to play in providing access to high quality STEM education to students in every state. We must provide our citizens with the problem-solving skills needed for the lifelong learning that is now required to adapt and thrive in a rapidly changing job market, one often driven by advances in S&E. To achieve these outcomes, we must facilitate and deepen partnerships between educational institutions and industry to prepare individuals for the industries of the future.

While the need to improve our K-12 STEM education and to build a STEM-capable U.S. workforce are not new challenges, rising global competition, the increasing importance of S&E to our economy and security, and to individual opportunity make finding ways to move the needle on math and science competency and build a truly inclusive STEM-capable workforce more vital than ever.

---

[9] National Science Board (2019). "Elementary and Secondary Mathematics and Science Education," *Science & Engineering Indicators 2020*. NSB-2019-6.
[10] National Science Board (2019). "The Skilled Technical Workforce: Crafting America's Science & Engineering Enterprise," NSB-2019-23.

Conclusion

As we see in *Indicators 2020*, there is more competition, collaboration, and knowledge production across the global S&E environment than ever before. Other countries are rapidly adopting the blueprint that has driven U.S. S&E leadership, economic prosperity, and security for the past seven decades.

It is important to remember that healthy competition in S&E benefits all of humanity. This global competition for talent and ideas is a challenge that will spur us to up our game.

Yet there is no denying that America's S&E enterprise faces headwinds, that if unaddressed, risk the S&E global leadership that we have enjoyed since 1950. As other countries invest in their S&E enterprises, ours is transitioning toward a smaller share of global discovery and innovation. Unless we take steps now, we could fall behind as other countries attract globally mobile scientists and engineers and we continue to make slow progress in fully developing our domestic talent. These factors could lead to future critical technologies being developed elsewhere, with potentially devastating impacts on our economy and national security.

To remain competitive in this new global environment, we must adapt more quickly through partnerships and collaborations, reaffirm our values, give Americans the STEM education, knowledge, and skills they need to thrive, and ensure we have the infrastructure and resources to provide a home for the world's best talent and ideas.

As I conclude, I return to the story of Dr. Whittingham, now at the State University of New York, where his continuing work to improve battery technology has been supported by NSF for over 30 years. He discovered a fundamental chemical property of specific solid materials, and *then* saw the potential applications of his discovery – taking him down a new, unexpected path that led to an invention that changed our world. Stories like this are why we need to attract and fund the best *people*, as well as the best ideas. For the U.S. to maintain preeminence in S&E, we need to develop and attract the best minds. Then we must give them the time and space – and resources – to explore, to not be sure exactly what they might find, or why it might be useful; but being sure in the knowledge that discovery will ultimately reap huge, unexpected benefits for humanity. We know this because we have seen this story of unleashed creativity play out, over and over again. It is what has brought us the technology-driven world we live in today – and it is what will bring us the innovations that will shape our tomorrows.

So what should we do as we look to the future? We believe that our nation should **be fearless**. We should look beyond anxieties about global competition, challenges to scientific openness, or current budget limitations. Instead, we should ask how we can lead the next era of science and engineering - embracing America's identity as the land of opportunity, remembering the can-do attitude that defines our people, and racing to lead a future in which ideas are forged on a global scale. We can do this if we unleash the strength of our values – a spirit of exploration, of wonder, of discovery; coupled with a willingness to take risks and an emphasis on freedom and individual creativity – to ensure America's continued preeminence in research and innovation in the 21st century.

Because the best way to lead the future is to invent it.

Diane L. Souvaine

Biography

Computer Science and Mathematics
A.B. c.l., English & Mathematics, Harvard University
M.A.L.S., Mathematical Sciences, Dartmouth College
M.S.E., Electrical Engineering & Computer Science, Princeton University
M.A., Computer Science, Princeton University
Ph.D., Computer Science, Princeton University

Dr. Diane L. Souvaine, Professor of Computer Science and Adjunct Professor of Mathematics, has been a member of the Tufts University faculty since 1998. She served as Vice Provost for Research from 2012-2016, Senior Advisor to the Provost from 2016-2017, and Chair of the Department of Computer Science from 2002-2009.

Prior to Tufts, Dr. Souvaine was a member of the Rutgers University faculty for 12 years. During her tenure at Rutgers, she served for 2.5 years in the Directorate of NSF's Science and Technology Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), a groundbreaking academic/industry collaboration of Princeton, Rutgers, Bell Labs and Bellcore. DIMACS is tasked with both the theoretical development of mathematics and computer science and their practical applications.

Dr. Souvaine's research contributions range from solving challenging problems in computational geometry to practical application across disciplines. Her work extended the results of straight-edged computational geometry into the curved world. Visibility, triangulations and geometric graphs represent another focus of Dr. Souvaine's research as does the application of computational geometry to statistics. Her research led to consulting engagements with corporations such as Exxon Chemical Research, IBM and Pfizer.

Elected Chair in 2018, Dr. Souvaine is in her second term on the National Science Board to which she was appointed in 2008 and 2014. She previously served as Vice Chair from 2016-2018, has chaired NSB's Committee on Strategy and Budget and its Committee on Programs and Plans, and served on its Committee on Audit and Oversight, all of which provide strategic direction, and oversight and guidance on NSF projects and programs.

In addition to her scientific and policy contributions, Dr. Souvaine is dedicated to increasing diversity and advancing women and underrepresented groups in mathematics, science, and engineering and works to enhance pre-college education in mathematics and computational thinking.

Dr. Souvaine is a Fellow of the American Association for the Advancement of Science (AAAS) and of the Association for Computing Machinery (ACM), and was a 2005-2006 Fellow of the Radcliffe Institute for Advanced Study. Among many other accomplishments, she was the recipient of the 2008 Lillian and Joseph Leibner Award for Outstanding Teaching and Mentoring.

Chairwoman JOHNSON. Thank you very much. Dr. Schmidt.

TESTIMONY OF DR. ERIC SCHMIDT,
FOUNDER, SCHMIDT FUTURES

Dr. SCHMIDT. Thank you very much. I completely agree with Dr. Souvaine and also to your two initial statements, Chairwoman Johnson, Ranking Member Lucas, and thank you for letting me be here.

When I was a graduate student, I was funded by National Science funding as well as DARPA funding. Without that funding, I would not have been able to do the kind of research that at the time allowed my career to become what it is today.

During that time, I was CEO of Google and I'm now the Chairman of two essentially national security or DOD commissions. Larry and Sergey, when they worked at Stanford, were funded by National Science Foundation grants. There were plenty of examples where government initial basic research funding in key areas that were thought to be promising created enormous wealth for our Nation and made it globally competitive. I can give you example after example, as you pointed out.

My message today is one of urgency. Business as usual seems awfully pleasant and fine, but it's not going to deal with the challenges that we face from a standpoint of global leadership and national security. As an example, China is clearly and aggressively trying to close the lead that we have between them and emerging technologies. In a most recent public announcement they said that they wished to lead and in fact surpass the United States in the following areas: Quantum communications, supercomputing, aerospace, 5G, mobile payments, new energy vehicles, high-speed rail, financial technology, and AI, which is everything I do, right, and everything everybody here really cares about. These guys are smart, and they know what they're going to focus on.

Now, we have studied this pretty carefully, and at the moment we are ahead in AI. We're ahead by some number of months or years, and the number is not large. There's every evidence that our current lead is very, very fragile and that China will catch up and perhaps surpass for the reasons that Dr. Souvaine already talked about. Some of the numbers, there are about 15 times as many deployed 5G base stations in China as in the United States. Chinese researchers are expected to overtake Americans in the 1 percent of the most cited scientific papers in AI. By 2030 China is expected to in actual terms be larger than the U.S. in terms of R&D.

So this competition with China is not zero-sum. A simplistic model would be to decouple, and that would be very damaging to America for the reasons that have already been outlined. And yet we need to recalibrate this. Espionage and intellectual property thefts, everyone here is aware of these things. We have to address those. Our model, which is a model of free and open society with people coming in, new ideas, and so forth, should be the model that wins, but it's under challenge today.

As the Ranking Member said, the best defense is a good offense. I simply want America to win, and I think we all agree on that. So what is it going to take? How do we win in this incredible com-

petition that's going to play out in the next decade? I have six proposals, which are just real quick.

The first is we're going to need to take the core R&D funding and double it, as you already discussed in your statement. And we're probably going to have to double it again after that, but let's start by the first doubling. Let's grow this, let's invest in it. We really, really need that as a Nation. There are plenty of very, very good targets for this that will help the country in all sorts of ways.

Second, in infrastructure—I'll just be blunt, we need an alternative to Huawei. We need a U.S. alternative that we're proud of and that works and so forth and so on, including spectrum sharing with the DOD, et cetera. With grants, and the way they work, we've been studying—and I've been looking at the NIH model. They have a pretty good model. They do multiyear investments in promising individuals, and let them sort of begin to build these new patterns of thought and build the ultimate institutions that lead our Nation.

With respect to partnerships, there are so many examples where the government and industry and universities can work better. I'll give you an example. I think there's a huge problem with lack of cloud resources, cloud computing resources, so there are various proposals from your organization and others which are around national research clouds, access to the computing power that's needed to get these powerful algorithms to really bring them to their top ability.

In talent, we've spent lots of time in the last few years talking to the government about AI, and the core problem, to be very, very blunt, is that the knowledge about AI is so specialized and very, very few of those people are in government. We need a path, a plan, and an approach that will get that talent into the government one way or the other—training, hiring, mergers, partnerships, you name it.

And then finally—and this is something which is not talked enough about—is that the Chinese have great confidence in AI. Seventy percent think it will make their country better. When you ask the same question to Americans, only 25 percent. We've got to address this. We've got to address concerns of which there's a long list: Privacy rules, investing in security, technical standards, avoiding algorithmic bias, preparing for the workforce impacts, which will eventually come from these technologies a long time from now. All of these things we have to address.

So my point here is let's get ourselves onto a more urgent footing. This is going to be a big fight. It's going to be important. It's crucial to our national security, and it's important for our Nation and our Nation's identity, innovation, and, frankly, our economic growth. Thank you very much.

[The prepared statement of Dr. Schmidt follows:]

Testimony of Dr. Eric Schmidt

U.S. House of Representatives Committee on Science, Space, and Technology

Hearing Titled: "Losing Ground: U.S. Competitiveness in Critical Technologies"

January 29, 2020

Chairwoman Johnson, Ranking Member Lucas, and Members of the Committee, thank you for the opportunity to testify on the importance of U.S. competitiveness in critical technologies. I appear today as a long-time advocate for federal government investments in technology research and development, having seen first hand how these investments can bolster America's competitiveness in the global economy. I am proud to have been CEO of Google, and recall how the National Science Foundation helped fund the scientific advances that Google co-founders Larry Page and Sergey Brin commercialized so successfully to build the first broadly adopted search engine. I have also focused on understanding the role of new technology in protecting our national security, as chair of two government panels -- the National Security Commission on Artificial Intelligence and the Defense Innovation Board. Today, however, I am speaking not as a representative of these organizations, but as a private citizen.

I commend the Committee for the breadth of this hearing. The range of technologies discussed today must be understood as interconnected opportunities. Advances in quantum computing will spur developments in AI, progress in AI will help accelerate discoveries in biotechnology, 5G networks will open up new opportunities to leverage AI applications, and so on. We must find an integrated approach to federal investments across emerging technologies. Doing so requires a comprehensive national strategy, to set and reinforce priorities and to reconcile budget tradeoffs. This Committee has a central role in that urgent project.

My central argument is this: If we do not make serious investments now, we stand to lose our global leadership position in critical technology areas by the end of this new decade, with significant consequences for our country's prosperity and security.

I will offer my view on the imperative of global technology leadership and our complex technology competition with China, and then offer a series of proposals for this Committee's consideration. I will focus mainly on AI and associated issues such as advanced computing, but many of my points are applicable more broadly. Based on my recent experience working with the defense and intelligence communities, I also want to emphasize the national security dimensions of these issues. The AI Commission's recently published Interim Report expands upon some of these points, and I have attached it here for the Committee's reference.

Global Technology Leadership

Holding a global leadership position in emerging technology is both an economic and a national security imperative. Innovation is the foundation of the U.S. economy, as well as the

source of the military advantage that protects us and our allies and deters aggressors. Leadership gives our security agencies access to the best available technologies, and puts the United States in the best position to secure them against vulnerabilities and develop standards for their responsible use.

Because the commercial sector vastly outspends the government on R&D, the government must partner more closely with private companies to shape technology development. The commercial sector alone will not meet every or even most of our economic competitiveness or security needs. The U.S. government must prioritize and catalyze. The government's responsibility is to steer advancements in ways that protect Americans, preserve a robust basic research environment, and fill gaps where commercial enterprises have not focused their attention or resources.

The United States now faces an economic and military competitor in China that is aggressively trying to close our lead in emerging technologies. Many Americans still have an outdated vision of China. In three generations China transformed from having a per capita income of about $90 in 1960 to about $10,000 today.[1] China has already passed the United States in GDP based on purchasing power parity. China poses a larger economic challenge than the Soviet Union did. As a leading historian recently noted, "the Soviet Union could never draw on the resources of a dynamic private sector. China can."[2] Now, the Chinese government has ambitions -- and specific plans, with promises of billions of dollars in funding -- to surpass the United States in areas such as quantum communications, supercomputing, aerospace, 5G, mobile payment, new energy vehicles, high-speed rail, financial technology, and AI.

With AI in particular, where do we stand today? By most estimates the United States is the global leader in 2020. There are many different metrics and I won't go into them here. But consider the most recent attempt to do a comprehensive assessment, called the Global AI Index, which measured 150 indicators. It found the United States is the "undisputed leader" in AI development, with a score almost twice that of China, which placed second.[3]

But now consider how fragile that lead is. The same study projected that based on current AI trends, China will overtake the United States in only five to ten years. From my own experience, which includes frequent interaction with China's technology community, I think that's about right.

Many data points and observations lead me to such a projection. Here are just a few. Today, China has almost twice as many supercomputers as the United States. It has approximately

---

[1] World Bank, "GDP per capita (current US$) - China." (2018), https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=CN.
[2] Niall Ferguson, "The New Cold War? It's With China, and It Has Already Begun," New York Times (Dec. 2, 2019), https://www.nytimes.com/2019/12/02/opinion/china-cold-war.html.
[3] Tortoise Media, "The Global AI Index" (Dec. 2019), https://www.tortoisemedia.com/intelligence/ai/.

15 times the number of deployed 5G base stations as the United States.[4] By 2025, Chinese researchers are expected to overtake American researchers in the one percent of most-cited scientific papers in AI.[5] By 2030, China is expected to spend more than the United States on overall R&D, in absolute terms.[6] Sometime after 2030, the Chinese economy likely will become larger than ours.[7]

In other words, unless trends change, we will be competing with a country that has a bigger economy, more R&D investments, better quality research, wider application of new technologies, and stronger computing infrastructure. As the 2020s begin, we should be gearing our policy and legislation to compete effectively in a 2030s world that may look very different.

Complex Competition with China

The technology competition with China is not straightforward or zero sum. Speaking of an arms race is too simplistic. We should not only compete with the Chinese but also work with them. Many breakthroughs in one country will benefit researchers in the other, because they are openly available -- or were produced through cooperation. In the AI field, for example, the number of research papers published with American and Chinese co-authors has doubled in the last decade.[8] Chinese nationals are important contributors to U.S. universities and research institutes. There are many areas where cooperation would have clear mutual benefits, for example in AI-based approaches to climate challenges, disaster relief, and health care. We should also engage in collaborative discussions on AI safety -- that is, ensuring AI systems only do what they are designed to do.

Simple decoupling is unwise because it would significantly harm the United States. Still, there are aspects of the U.S.-China technology relationship that need to be recalibrated. China's well-documented espionage, intellectual property theft, and talent recruitment programs are disadvantaging our companies, our universities, and our military. The findings of a recent Senate investigation into China's methods to unfairly exploit U.S. taxpayer-funded research for its own benefit is a case in point.[9] I commend the intense focus in Congress on these issues.

---

[4] Stu Woo, "In the Race to Dominate 5G, China Sprints Ahead," Wall Street Journal (Sept. 7, 2019), https://www.wsj.com/articles/in-the-race-to-dominate-5g-china-has-an-edge-11567828888

[5] Field Cady and Oren Etzioni, "China May Overtake US in AI Research," Allen Institute AI2Blog (Mar. 13, 2019), https://medium.com/ai2-blog/china-to-overtake-us-in-ai-research-8b6b1fe30595.

[6] "2018 Global R&D Funding Forecast," R&D Magazine (Winter 2018).

[7] See James Manyika and William McRaven, "Innovation and National Security," Independent Task Force Report No. 77, Council on Foreign Relations (Sept. 2019), https://www.cfr.org/report/keeping-our-edge/pdf/TFR_Innovation_Strategy.pdf.

[8] Sarah O'Meara, "AI Researchers Want to Keep Global Sharing Culture Alive," Nature (May 29, 2019), https://www.nature.com/articles/d41586-019-01681-x.

[9] "Threats to the U.S. Research Enterprise: China's Talent Recruitment Plans," Staff Report, U.S. Senate Permanent Subcommittee on Investigations (Nov. 2018), https://www.hsgac.senate.gov/imo/media/doc/2019-11-18%20PSI%20Staff%20Report%20-%20China's%20Talent%20Recruitment%20Plans.pdf.

But as we find areas for prudent disengagement, we should bear in mind that unwinding the complex web of connections between our countries -- people, hardware, supply chains, investments, research -- will have costs, and possibly consequences we don't foresee, for our economy and research system. We should take careful stock of our choices.

The way to technology leadership is a dual path: better protect our innovations, and out-innovate our competitors. The best outcome is having U.S. tech firms out-compete their global competition on a more level playing field to win greater market share, and to integrate that world-leading technology into our government agencies to use in national security missions.

We also need to reframe the bilateral disputes in a more global context. Technology developments, especially in AI applications and 5G infrastructure, are pointing toward a world that risks becoming divided into technological and ideological spheres of influence. This world would have American and Western technologies predominant in some regions and Chinese systems more established in others. We do not seek a divided world, but neither do we want to live in a world shaped by China's view of the relationship between technology and governance.

For example, Chinese companies already supply AI surveillance technology to 63 countries, according to a recent study.[10] China's so-called "digital silk road" initiative could provide technology infrastructure to enable more governments to impose the authoritarian norms found in China -- including the disappearance of individual privacy under state surveillance, and the repression of speech and expression through state censorship.

My concern is that as China tries to fulfill a vision of high-tech authoritarianism, that governing model will appeal to other governments searching for a foundation on which to exercise their power. It is incumbent upon our country and other free societies to present a model of high-tech democracy that is even more compelling and economically viable, because it preserves foundations of individual freedom.

So U.S. technology leadership is imperative not only for our economic competitiveness and for our military advantage -- it is also imperative to uphold the democratic model of governance and prove its resilience in the face of technological changes that could be used to threaten it.

What To Do Now

Let me turn to some nuts and bolts of what the U.S. government -- and this Committee in particular -- can do to change current trends and extend U.S. technology leadership. The past year has seen several positive steps, such as the National Quantum Initiative, progress in the Energy

[10] Steven Feldstein, "The Global Expansion of AI Surveillance," Carnegie Endowment for International Peace (Sept. 2019), https://carnegieendowment.org/2019/09/17/global-expansion-of-ai-surveillance-pub-79847.

Department's exascale supercomputer project, and NSF's new initiative to build a series of AI research institutes. Here are six proposals that would have a broad impact on new technology development in the United States. They focus on civilian investments, given the jurisdiction of this Committee, but they could also benefit military competitiveness. Many are described with more context or detail in the AI Commission's report.

1) Funding: Overall federal R&D spending has not kept pace with technological change. Simply put, we need to place big bets. U.S. government funding for R&D has seen a decades-long decline, and is now at pre-Sputnik levels as a percentage of GDP.[11] For AI, the scale of investment should be multiple times current levels. In computer science in particular, more research funding is critical to help stabilize academic research and mitigate a brain drain from academia to industry. Student enrollment in computer science classes has skyrocketed, but universities aren't retaining enough faculty to teach this next generation.

2) Nationwide Infrastructure: Given the interconnected nature of emerging technologies, we must invest in foundational infrastructure. This includes supporting a competitive and secure global alternative to Huawei in 5G, ensuring the U.S. microelectronics supply chain is resilient and assured, and investing in next-generation and high-performance computing. Congress should consider national models that have worked well, such as the National Nanotechnology Initiative. Launched in 2000, that effort integrated the work of 20 government bodies and prompted huge growth in the nanotech field, including a network of labs and research centers across the country.

3) Flexible Grants: The United States graduates the largest number of science and engineering doctorates of any country. We need new mechanisms to accelerate expert research. Congress should consider models for multi-year investments in promising individuals, not just specific projects, as is done at the Howard Hughes Medical Institute and through the Defense Department's Vannevar Bush faculty fellowships.

4) Government–Industry–Academia Collaborations: Partnerships can help researchers overcome technical and financial barriers, as NSF is doing through its CloudBank initiative to connect NSF-sponsored researchers to cloud computing resources. This could expand into a nation-wide National Research Cloud. Congress should also explore tax incentives for companies to share data and provide computing capabilities to research institutions, and accelerate efforts to make government datasets more widely available.

[11] In 1953, the U.S. spent 0.72 percent of its GDP on R&D. In 1957, when the then-Soviet Union launched Sputnik, it had grown to 1.3 percent. R&D spending peaked at 1.86 percent in 1964. In 2017, it declined below 1953 levels to 0.61 percent. Federal R&D Budget Dashboard, American Association for the Advancement of Science, https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd.

5) Talent Development: The United States needs major new STEM education initiatives at the K-12, college, and graduate levels. This includes expanding the existing STEM scholarship programs and designing new ones. We also need to attract more global expertise to America. Around 80% of computer science PhD students who come from abroad to study end up staying in the United States after graduation.[12] Students all over the world want to study here, and we should make it easier for them to stay. That helps our competitiveness. But more countries are trying to recruit science and technology experts -- not just China, but also friends like Canada -- through immigration and work incentives. Experts in fields like AI have highly-specialized skills and are in demand. The more competitive our talent retention policy, the better our chances to lead.

6) Public Confidence: If we do not earn the public's trust in the benefits of new technologies, especially AI, doubts will hold us back. An international survey found that China has a huge lead in public confidence in AI: 70% of Chinese said they trust AI technology, compared to 25% of Americans.[13] Legislators, researchers, and tech companies need to confront the concerns Americans have, while also communicating the great potential to improve lives. That means, among other things, enhancing privacy rules, investing in security research, developing technical standards, and preparing for workforce impacts from more automation.

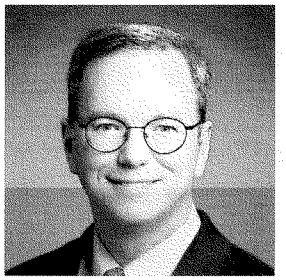
* * *

In sum, U.S. global technology leadership is an imperative, and there are near-term steps this Committee can take to extend our leadership in new technologies beyond what many experts currently predict. The Defense Innovation Board has published many other recommendations, and the AI Commission is preparing more detailed prescriptions, and will provide them on a rolling basis as they are developed, leading up to a final report next year. Thank you again for the chance to appear today, and I look forward to your questions.

---

[12] Remco Zwetsloot, Roxanne Heston, and Zachary Arnold, "Strengthening the U.S. AI Workforce: A Policy and Research Agenda," Center for Security and Emerging Technology at iii (Sep. 2019), https://cset.georgetown.edu/wp-content/uploads/CSET_U.S._AI_Workforce.pdf; see also Science & Engineering Indicators 2018, National Science Board (2018), https://www.nsf.gov/statistics/2018/nsb20181/assets/901/tables/tt03-27.pdf.

[13] Ipsos, "The Emergence of Social Entrepreneurialism to Compete with Business Entrepreneurialism," (Nov. 12-18, 2018), https://www.ipsos.com/sites/default/files/ct/news/documents/2018-10/entrepreneurialism-2018-global-report.pdf.



Biography of

Dr. Eric Schmidt

Eric Schmidt is Founder of Schmidt Futures.

Eric is also Technical Advisor to Alphabet Inc., holding company of Google Inc, where he advises its leaders on technology, business and policy issues.

Eric was Executive Chairman of Alphabet from 2015-2018, and of Google from 2011-2015.

From 2001-2011, Eric served as Google's Chief Executive Officer, overseeing the company's technical and business strategy alongside founders Sergey Brin and Larry Page. Under his leadership, Google dramatically scaled its infrastructure and diversified its product offerings while maintaining a strong culture of innovation, growing from a Silicon Valley startup to a global leader in technology.

Prior to joining Google, Eric was the chairman and CEO of Novell and chief technology officer at Sun Microsystems, Inc. Previously, he served on the research staff at Xerox Palo Alto Research Center (PARC), Bell Laboratories and Zilog. He holds a bachelor's degree in electrical engineering from Princeton University as well as a master's degree and Ph.D. in computer science from the University of California, Berkeley.

Eric was elected to the National Academy of Engineering in 2006 and inducted into the American Academy of Arts and Sciences as a fellow in 2007. Since 2008, he has been a trustee of the Institute for Advanced Study in Princeton, New Jersey. Since 2012, Eric has been on the board of the Broad Institute and the Mayo Clinic. Eric was a member of the President's Council of Advisors on Science 2009-2017. In 2013, Eric and Jared Cohen co-authored The New York Times bestselling book, *The New Digital Age: Transforming Nations, Businesses, and Our Lives*. In September 2014, Eric published his second New York Times bestseller, *How Google Works*, which he and Jonathan Rosenberg co-authored with Alan Eagle. In April 2019, Eric published his third New York Times bestseller, *Trillion Dollar Coach: The Leadership Playbook of Silicon Valley's Bill Campbell*, which he co-authored with Jonathan Rosenberg and Alan Eagle.

Eric became the Chairman of the Department of Defense's Innovation Board in 2016 and was awarded the Department of Defense Medal for Distinguished Public Service in January of 2017 by Secretary of Defense Ashton Carter. He is Chairman of the US National Security Commission for Artificial Intelligence. He is a member of NASA's National Space Council User Advisory Group which is chaired by the Vice President. Eric is an MIT Visiting Innovation Fellow, member of the Advisory Board for MIT IQ, member of the MIT Commission on the Work of the Future, member of the MIT CEO Advisory Board, and member of the MIT Schwarzman College of Computing Advisory Council. Eric is founder of Schmidt Futures which helps exceptional people do more for others by applying science and technology thoughtfully and working together across fields.

Chairwoman JOHNSON. Thank you very much. Dr. Abdallah.

TESTIMONY OF DR. CHAOUKI ABDALLAH,
EXECUTIVE VICE PRESIDENT FOR RESEARCH,
GEORGIA INSTITUTE OF TECHNOLOGY

Dr. ABDALLAH. Good morning, Chairwoman Johnson, Ranking Member Lucas, and Members of the Committee. Thank you for inviting me to address the topic of U.S. competitiveness with the focus on critical technologies and their economic and security implications from the vantage point of a research university.

As you heard, I'm Chaouki Abdallah. I'm the Executive Vice President for Research at Georgia Tech, a leading public research university. We are a community of more than 9,000 faculty, researchers, and staff, and we're incredibly proud to be serving about 36,000 of the brightest students from around the world. Within that community is also the Georgia Tech Research Institute, GTRI, an Army-university-affiliated research center.

Like other universities, we benefited from Federal investments in research, and we contribute to the knowledge, creation, and economic activities. And until recently, as you just heard, most observers would have agreed with the assessments that, thanks to the national research strategy set more than 7o years ago, that the U.S. was indeed the undisputed leader in science and technology funding and in applications.

The mission alignment and cooperation of three actors: The Federal Government, higher education institutions, and the private sector—have historically made the U.S. research landscape the most productive and admired in the world. But with that we attracted collaborators but also we became a target to competitors and foes who have sought to exploit the fruits of our research.

And today, as you read in the National Science Board's recent report, "The State of U.S. Science and Engineering 2020," increasingly, the United States is seen globally as an important leader rather than the uncontested leader. And this is especially true in some of the critical technologies that we're addressing or discussing today.

As detailed in my written testimony in a recent think-tank report, the risk of falling behind in critical areas and others pose an immediate national security risk and also a long-term economic risk. Achieving quantum supremacy, for example, will affect our current encryption systems. And materials that may be designed using machine learning algorithms are needed to achieve hypersonic flight.

I do believe that the economic impact will manifest itself in the following way: Our ability to create new knowledge and industries will be diminished, thus impacting our economic health and competitiveness; reducing our ability to attract the best and the brightest and leading to further weakening of our national security and economic health.

It is notable that the Office of Science and Technology Policy, the OSTP, through the Joint Committee on Research Environment, has initiated various initiatives to address urgent challenges facing research competitiveness. Organizations such as the AAU (Association of American Universities) and the APLU (Association of Public

and Land-grant Universities) have commented on such initiatives, and I agree that the research universities will play an increasingly critical role in preparing, recruiting, and educating a diverse pool of STEM talent but also in maintaining our collaborative efforts with our allies and producing knowledge that will improve the human conditions, all while supporting the national and economic security of the Nation.

Through your efforts and in collaboration with higher education institutions and the private sector, we will modernize the research model that served us so well and has led to STEM sector generating more than $2 trillion in taxes per year, as well as supporting more than 2/3 of the U.S. jobs.

In the face of the competitive challenges from other nations, as you heard, and the complex global problems the Federal Government has an even larger role to play in funding and guiding long-term research, while harmonizing many of the conflicting reporting and compliance requirements. It is also incumbent upon American universities to continue to strengthen their collaboration with the Federal agencies and government and with industry and to assume more responsibility outside of our traditional roles. Universities must become ready for the students they admit, as well as to admit college-ready students while scaling up the basic and applied research activities that made many of them economic engines. They must also continue to collaborate while protecting sensitive data and research.

One of the best opportunities and most enduring strategies for improving our S&T position is obviously to nurture and engage a larger number from untapped domestic populations and to provide an academic environment for them to strive and succeed as students, faculty, and researchers. My colleague, the Dean of the College of Computing at Georgia Tech, remarks that it's one thing to be in front of someone and not be seen but quite another to not be in front of someone and to never have your absence noticed. The absence of large portions of our citizens within the S&T enterprise is definitely being noticed and felt. Research universities are committed to working closely with the Federal Government and the private sector to produce S&T workforce that is more reflective of our society.

I thank you again for the invitation to speak with you and look forward to your questions.

[The prepared statement of Dr. Abdallah follows:]

Statement of
Dr. Chaouki T. Abdallah
Executive Vice President for Research
Georgia Institute of Technology

before the

Committee on Science, Space, and Technology
U.S. House of Representatives
January 29, 2020

Chairwoman Johnson, Ranking Member Lucas, and members of the committee — thank you for inviting me to address the topic of U.S. competitiveness with a focus on critical technologies and their economic and security implications from the vantage point of a research university.

As you just heard, I am the executive vice president for Research at Georgia Tech, one of the leading research universities in the world, and a public one at that. Prior to returning to Georgia Tech, I was provost, and for a brief period of time, president, of the University of New Mexico, another public research university. I stress the public mission of my current and previous institutions because of the significant role such institutions play in postsecondary education and in research and innovation — and the importance of federal and public investments in their mission. Public institutions educate 74% of college-age students in the U.S. and conduct about two-thirds of all university-based research, and are critical in educating and diversifying the future workforce.

Beyond being a proud public institution, Georgia Tech is unusual among research universities in one other aspect, namely the presence of the Georgia Tech Research Institute (GTRI), the Institute's applied research division. GTRI is comprised of more than 2,000 scientists, engineers, support professionals, and students who help solve the most difficult problems facing government and industry across the nation and around the world. Notably, GTRI is also an Army University Affiliated Research Center (UARC), through which we provide substantial advanced science and technology expertise in support of multiple national security customers across the federal enterprise.

Let me first quickly frame the history and current state of the U.S. research and development (R&D) enterprise in relation to other nations. Until recently, most observers would have agreed with past assessments that the U.S. was the "undisputed leader" in science and technology funding and applications. Instead, as reported in the National Science Board (NSB)'s "The State of U.S. Science and Engineering 2020" report released earlier this month, "increasingly the United States is seen globally as an important leader rather than the uncontested leader."

The modern U.S. research enterprise was born out of the foresight and wisdom of political and scientific leaders who called for direct government support for science, and made the case for the creation of a national research strategy and the National Science Foundation 70 years ago. The model they established has served us well, and has been emulated in other countries. It stresses the important role of the federal government in funding independent research at universities, and

the responsibility of those universities to work on the problems that improve the well-being of the citizenry, as well as the human condition. Later policies such as the Bayh-Dole Act have entrusted universities with intellectual property funded by the taxpayers, and encouraged them to work with the private sector to bring such intellectual property to market. The federal dollar is usually the first dollar in the chain, and is converted by universities into basic knowledge and talent, feeding businesses and leading to solutions, technologies, and products that generate returns back into the federal treasury and benefits to society.

The federal government, through its unique network of national laboratories and agencies such as NSF, NIH, NASA, DARPA and others, has also maintained a complementary but key role in supporting and guiding long- and medium-term research. Industry and business investments in R&D continue to ebb and flow, but in 2000, they surpassed the amount invested by the federal government. It is however the mission alignment and cooperation of the three actors — the federal government, higher education institutions, and the private sector — that has historically made the U.S. research landscape the most productive and admired in the world.

As an example, investments by private entities such as Bell Laboratories laid the groundwork for the communication and electronics industries, and NSF's federal investments in basic research at universities led to the creation of many successful high-tech companies. The system continues to work well, and we are all beneficiaries of the policies and investments made by earlier generations of leaders and researchers. Moreover, the dynamism and long-term certainty as well as the openness of the U.S. research model has served as a powerful attractor for global talent, and a birthplace of innovative ideas and industries.

Today, however, the once undisputed power of our model is being challenged. While we remain leaders in most critical areas, various friends and foes, have quickly closed the gap. If current trends continue, some will pull ahead of us in the near future. In fields such as quantum information science and technology and artificial intelligence, countries other than the U.S. are already ahead. As the aforementioned NSB report also states, the U.S. continues to lead globally in R&D expenditures, in the production of science and technology (S&T) doctorates, and in producing highly cited research publications, but other nations, namely China, are rapidly increasing their investments and developing their own science and engineering capacity. In other words, while we currently remain at the head of the pack, leading indicators such as S&T first degrees (associate and bachelors) and number of patents paint a worrisome picture about our future position in many important areas.

These important areas include critical technologies such as artificial intelligence, cybersecurity, next generation wireless, quantum information systems, advanced manufacturing and materials, bioscience and engineering, and many others. It is important to keep in mind, however, that what is now a critical technology was once a basic science research idea, or likely fundamental research funded by the federal government at a research university. For example, quantum information systems are direct descendants of quantum mechanics theory while artificial intelligence algorithms and products were, until recently, theoretical mathematical results.

The key role such critical technologies play in our national security is clear. Achieving quantum supremacy, for example, will affect current encryption systems, and materials that may be

designed using machine learning are needed in achieving hypersonic flight. As you know, the economic impact of falling behind in such areas is significant. I believe that it will manifest itself in the following ways:

1) **A reduction in our ability to create new industries and the resulting impact on our economic health and competitiveness.** As I mentioned earlier, many of our current businesses are trees that grew from the seeds of past federal investments, and most were not anticipated by their original creators. Knowledge is being created everywhere and is traveling ever faster and farther — and, unlike physical resources, knowledge is not depleted when used. The best job creation and economic development strategy remains an investment in creating such knowledge and the pipeline to transform that knowledge into complex products in critical technologies and beyond. In failing to do so, we risk becoming a country that imports more advanced finished products. This has already manifested itself in areas such as solar cells and various computer components. It has also lessened our competitiveness in future growth areas such as clean energy products.

2) **A costly game of playing catch-up.** The rate of knowledge acquisition and propagation keeps accelerating, and once we fall behind, catching up becomes costlier than keeping our lead. Today, China's annual R&D growth rate is 18%. By contrast, the growth rate in the U.S. is around 4%. If and when China does surpass the U.S., we would need to further accelerate our own spending in order to remain competitive. It is also notable that the quality and impact of research produced by China are increasing along with its quantity.

3) **A dwindling attractiveness to the best and brightest minds from around the world.** Ultimately, talent and creativity are very dynamic and movable. Witness, for example, how certain regions of our country have become hubs of innovation and are attracting the highest quality talent from around the nation and the world. The same phenomenon is happening at the global level, at much higher stakes for our national and economic security. If we do not remain at the forefront of innovation, our appeal to talent is lessened, which further compounds the negative consequences I've just described.

While there are many actions that our nation is taking and can take in order to reverse the trend, I believe the following four are the most impactful:

1) **A commitment to the long-term increase and certainty in federal investment.** The research enterprise, while used to foster big ideas and big bets, needs the certainty of long-term planning and funding. Our funding agencies already realize that and fund multiyear programs and large centers, but government shutdowns and sequesters — as well as the disruptions of predictable funding sources that result from abrupt policy reversals — can have a rippling effect for universities such as Georgia Tech. This is especially risky as long-term commitment to researchers and research infrastructure becomes uncertain.

   Federal investment must continue to flow steadily in order to continue priming the pumps of the research enterprise, and to maintain a predictable and increasing flow of talent and

ideas. Federal funds often play multiple roles: They help recruit, educate, and retain top talent, support research facilities, and create intellectual property that leads to new markets and enterprises. At Georgia Tech, for example, we have leveraged federal research funds, along with state and industry support, to create a vibrant entrepreneurship culture and innovation centers. Such activities have served to attract students as well as a new generation of researchers and entrepreneurs. Increasing and maintaining funding to agencies such as NSF, NIST, NOAA, Office of Science, ARPA-E and others, also sends positive signals to the greater research enterprise, encouraging students to pursue S&T studies, and companies to invest in their own R&D.

2) **A reduction in bureaucratic burdens on conducting research.** I commend Dr. Kelvin Droegemeier, the director of the Office of Science and Technology Policy (OSTP) for making this issue one of his top priorities. While it is true that industry R&D expenditures currently exceed those of the federal government overall, it is also true that the second largest portion of the R&D funds expensed at universities comes from internal university resources. A large portion of those expenditures are required to safeguard the quality and integrity of research, but as indicated by the OSTP, some requirements are duplicative and need to be streamlined. Legitimate concerns around research rigor, integrity, replication, and data sharing are highlighted in the OSTP request for information on the American research environment. While the research administrative and security costs are increasing, policies that help align compliance requirements and reporting will redirect precious human and financial resources toward the actual research and critical safeguards.

3) **A commitment to cooperate where we should and compete where we must.** We must absolutely protect what must be protected, as evidenced by recent reports on undue foreign influence. Today's science is like today's problems — global — and our interconnectedness, both physical and virtual, has made us stronger yet interdependent. For example, the ability to share data allows us to inform each other of an upcoming natural or manmade disaster, but it also allows bad actors to remotely attack our infrastructure. Data collected and shared by businesses and governments is the fuel needed by artificial intelligence systems to make business decisions, or create personalized medical treatments.

   Sharing such data when appropriate increases its value and impact. It is vital that we collaborate to solve the big problems facing humanity, and to share our solutions as widely as possible when appropriate. Specifically, it is important that we increase our cooperation with allies who share our values in pursuit of technical and policy solutions to solve global problems, and to safeguard the resulting technologies. In light of the fact that other nations may actually be ahead in some critical scientific areas, cooperating with our allies has a multiplicative positive effect.

   On the other hand, we must become even more vigilant in protecting what must be protected. Recent reports such as the NSF-funded JASON report titled "Fundamental Research Security" highlighted a concerted effort to leverage our open research environment to gain an economic advantage. Leaders of other countries are copying our

nation's economic development playbook, and the stakes of that competition have never been higher for the U.S. More countries are also attracting their own students back — and recruiting American graduates and researchers as well. This is evident, in part, by the emergence of a competitive Chinese science system. Recent guidance by federal agencies is helping universities define and clarify how to protect sensitive yet unclassified information, and universities are engaged in efforts to make sure that conflicts of interests and commitments, whenever they arise, are properly managed. These are especially important around critical technologies, where the underlying research may not only be sensitive, but where the application of basic research, or the interconnection between various fields may create a serious risk to our national and economic security. I believe that Congress and government agencies play the most critical role in helping us increase cooperation with our collaborators, and matching the efforts of our competitors.

4) **Increased efforts to attract and retain a more diverse population into STEM.** There are international and national aspects to this strategy. We must regain our role as the strongest magnet for talent and creativity from around the world. The benefits of such a policy have already manifested themselves in the notable impact of foreign-born scientists, engineers, and entrepreneurs. It also seems obvious that such individuals, many of whom, like myself, were initially educated under a different educational system and funded by the resources of another country, bring with them a different way of thinking, learning, and problem-solving. Those unique perspectives, when coupled with our open research system and our American values, lead to a dynamic and healthy R&D enterprise.

   The demographic trends of the U.S. are also conspiring to reduce the number of U.S.-born, college-age students and graduates, furthering the need to attract international students and researchers. There also exists, however, a national and moral imperative to attract more U.S. students into higher education and, more specifically, to attract women and underrepresented minorities into STEM. The benefits of their diverse backgrounds and experiences are already felt in laboratories and companies, and the growth opportunity in such populations is obvious. That rich and diverse pool of candidates must be increased, prepared, and nurtured in the K-12 system. The best opportunity and most enduring strategy for improving our S&T position is obviously to nurture and engage a larger number from untapped domestic populations, and to provide an academic environment for them to strive and succeed as students, faculty, and researchers. My colleague, the dean of the College of Computing at Georgia Tech, remarks that it is one thing to be in front of someone and not be seen, but quite another to not be in front of someone and to never have your absence noticed. The absence of large portions of our citizens within the S&T enterprise is definitely being noticed and felt.

As I noted earlier, the cooperation between our federal government, our universities, and industry, has created a vibrant research enterprise and made the U.S. safer, healthier, and wealthier. The economic and social benefits of that system, however, have not been evenly distributed. As described in a recent op-ed by the president of the National Academy of Sciences and the president of Arizona State University, current and future challenges will require the participation of all segments of our population. The special role of American research universities in helping to create and govern critical technologies, is leading them to become more

proactive in recruiting and nurturing more diverse students. At Georgia Tech, for example, the "Focus" program is in its 26th year and has already encouraged more than 2,500 students from underrepresented populations to pursue graduate degrees, awarding fellowships to many of them and leading many of them to become university professors.

For most of their modern existence, universities have evolved steadily but slowly. The quickening pace of societal and technological change, however, also necessitates a re-examination of how universities are organized and how research is being conducted and rewarded. Universities must assume their own responsibility to be ready for the students they admit, as well as to admit college-ready students. We must continue to increase our efforts with K-12 schools to widen and diversify the pipeline of students and to embrace our role as economic engines. Universities that have better engaged with their communities, both in preparing their incoming students and in translating their research into practice, are also moving to measure and reward student success and economic development activities, in addition to the more traditional metrics of education and research. The complexity of current research challenges is also driving universities and funding agencies to knock down disciplinary boundaries and to move toward convergence research. Such research cries out for creative approaches, best achieved by assembling diverse and multidisciplinary teams. For example, at Georgia Tech, we organized our research efforts around interdisciplinary research institutes, and built educational programs across departments and colleges. We also established educational programs such as CREATE-X, Vertically Integrated Projects (VIP), and competitions such as the InVenture Prize to better prepare graduates for the fast pace of business.

I would like to end with a comment on the need for educating the whole person, rather than focusing solely on the very critical areas we discussed today. While I welcomed the opportunity to advocate for increasing support for critical technologies, we should not lose sight of the disruptive (mostly positive, but sometimes negative) effects such technologies can have on our society. We are keenly aware, for example, that AI technologies have ethical dimensions and employment implications for a large segment of our workforce. Such implications will affect the distribution of knowledge and wealth within and between countries, and must be accounted for by educators and policymakers alike.

Earlier this month, we celebrated the life of Martin Luther King Jr. In one of his writings, he discussed the purpose of education and wrote, "The purpose of education, therefore, is to teach one to think intensively and to think critically. But education which stops with efficiency may prove the greatest menace to society. The most dangerous criminal may be the man gifted with reason, but with no morals." A diverse workforce educated in civics and the humanities, in addition to STEM, will be best prepared to help create and manage future technologies. It is thus incumbent upon universities to provide an education that emphasizes the public purpose and implications of technology, a role that public and private universities have embraced. And as a nation, we must continue to make sure that as we invest in our critical technologies, that we also invest in ourselves.

Bio for Chaouki T. Abdallah

Chaouki T. Abdallah was appointed the Executive Vice President for Research (EVPR) at the Georgia Institute of Technology (Georgia Tech) on September 1, 2018. Prior to that, he was a professor of Electrical and Computer Engineering (ECE) at the University of New Mexico (UNM) where he served as Chair of the Electrical & Computer Engineering (ECE) department between 2005 and 2011and as Provost between July 2011 and August 2018. He also served as the 22nd President of UNM between January 2017 and February 2018. At Georgia Tech, Dr. Abdallah provides overall leadership for the research, economic development, and related support units within Georgia Tech, and serves on the President's executive leadership team. He also serves on the executive committee of the Council on Research for the Association of Public & Land-Grant Universities (APLU), the executive committee for the Government-University-Industry Research Roundtable (GUIRR), and the advisory committee for the Center on measuring university performance (MUP).

At UNM, Abdallah was the first recipient of ECE's Lawton-Ellis Award for combined excellence in teaching, research, and student/community involvement. Professor Abdallah also received the School of Engineering senior research excellence award in 2004, and was the ECE Gardner-Zemke Professor between 2002 and 2005. He received the 2017 UNM Staff Hero award for his "advocacy for staff during difficult financial times and for his support of Staff Council." He was the recipient of the 2017 Spirit of New Mexico award.

He has published eight books (three as co-editor and five as co-author) and more than 300 peer-reviewed papers. As Provost, he assembled a team to improve student success focusing on underprepared and underrepresented students. Within 7 years, under his leadership, UNM increased the first-year retention rates by 8%, the four-year graduation rate by 125%, the five-year graduation rate by 8%, and the six-year graduation rate by 15%, while closing the retention achievement gap and narrowing the graduation achievement gap. Abdallah obtained his Bachelor's of Engineering (BE) degree from Youngstown State University in 1981, and his MS and Ph.D. in Electrical Engineering from the Georgia Institute of Technology in 1982, and 1988 respectively. Abdallah conducts research and teaches courses in the general area of systems theory with focus on control, communications, and computing systems. Abdallah is a senior member of IEEE, is a recipient of the IEEE Millennium medal, and is fluent in English, French, and Arabic.

Chairwoman JOHNSON. Thank you very much. That completes the testimony of our witnesses. And now we will go to the questions. I yield myself 5 minutes.

Dr. Souvaine, I will begin with you. The National Science Foundation is celebrating its 70th anniversary this year. It is the only agency in our Federal Government dedicated to funding fundamental academic research across all fields of science and engineering, and the return on this investment over the last 70 years has been immeasurable.

However, the world has also changed in this time, and some policymakers and thought leaders are recommending that the NSF mission be broadened to include a deliberate focus on critical technologies. This might include, for example, creating a new directorate at NSF with its own dedicated budget line and more flexible DARPA-like authorities. How might such a directorate help advance U.S. competitiveness and critical technologies above and beyond the efforts already underway in the Federal Government? And how might we see it as a natural evolution of NSF's recent experiences such as convergence accelerators? And what steps would we need to take to ensure we continue to protect the essential basic research mission of NSF? Are there any potential concerns we should be looking out for?

Dr. SOUVAINE. Thank you, Chair Johnson. I think NSF has already begun the evolution toward trying to guarantee that the outstanding results that come from the basic research and the applied basic research at the Foundation move fluidly into translation and into having impact. So currently within each of the directorates there are activities underway that try to move things forward. Then if you look at underneath the leadership of Director France Cordova, the work on the convergence accelerators or the big ideas or if you look at I-Corps or you look at various different initiatives, NSF has been evolving already.

At the moment, as Dr. Schmidt has pointed out, though, things are urgent and we need to move faster still. We can't afford to leave our great innovations on the table and not pick up quickly. And suddenly that comes out of our S&E Indicators report from 2 weeks ago where we can show that in the U.S. we still fund more basic research than any other single entity, but others are funding more experimental research and are moving things forward more quickly. So we need to move things forward very quickly.

Certainly if we were to have a directorate focused on accelerating these new critical technologies, this would be a smart change and would help this process, but it can't be a choice between investing in what we need now and what we need in the future. So we're going to need both. A new directorate focused on critical technologies could not thrive without the basic research seed corn on which things like AI and quantum are built. So I'd hope that this kind of proposal would allow us to enhance the focus of all the other NSF directorates on the high-risk, high-reward, long-term basic research to discover and invent the critical technologies of tomorrow at the same time as we accelerate the critical technologies of today.

Chairwoman JOHNSON. Thank you. Dr. Schmidt?

Dr. SCHMIDT. I agree, and I would say that not only—well, first place, all of my friends in academia spend most of their time saying things that are much worse now. It's much harder to get funding early in their careers, and there's a long list of complaints. Partly it's because there isn't enough money and partly because things like the new directorate would—don't exist yet and they would help a lot. So I'm strongly in favor of that.

Chairwoman JOHNSON. Thank you. Dr. Abdallah?

Dr. ABDALLAH. I would also agree and I would suggest that it is really the two parallel tracks that we need to focus on. Just like Dr. Schmidt, I was funded by NSF. My own research was funded by NSF, and the work I was doing then was basic research, but it had a lot of applications later. You heard about Google. Google was—the original algorithm is actually very fundamental research that ended up creating a lot of economic activity, so I think we need to continue to do both.

Chairwoman JOHNSON. Thank you very much. My time is about expired. Mr. Lucas.

Mr. LUCAS. Thank you, Madam Chair. And I address my questions to the entire panel.

As I mentioned in my opening statement, having introduced legislation that would direct the development of a national science and technology strategy and quadrennial review like the process DOD undertakes for national security—and I know each of you touched on this, but expand for me if you would, please, just a little bit more about what you would like to see in a process of whole-government strategy for S&T and, as always, how that would benefit U.S. competitiveness, just whoever would like to take that.

Dr. SOUVAINE. Could you repeat the question?

Mr. LUCAS. Basically expand on your comments about what you would like to see in a process for a whole-of-government strategy on S&T and of course how that would benefit U.S. competitiveness. Because I have to explain things back home to my constituents, too.

Dr. SOUVAINE. So I think that the U.S. needs to compete with values, talent, partners, and research infrastructure. We need to nurture homegrown and foreign-born talent to build our STEM-capable workforce. We need to prepare our domestic students from every ZIP Code and every background to think creatively with the STEM concepts that touch every area of our lives. And we need to do a dramatically better job of preparing our domestic students.

At the same time, while we're doing this, we're dependent on foreign talent. We would leave the door open for the best and brightest, especially in the critical areas of computer science and math and engineering. We need to invest in critical areas of basic and applied science while supporting public-sector partnerships and development. And we need to be a reliable global partner and collaborator. Not doing so makes us a risk of becoming a victim of technological surprise when discoveries happen someplace else.

And sustaining our investment in fundamental research is a key competitive advantage, but we need to make sure that it leads to innovations and increase the efficiency of that process. That means fostering the partnerships between academia, industry, and govern-

ment and explore ways to break down the barriers that are preventing the fruitful partnerships right now.

And finally, we need to retain our foundational American values of freedom of inquiry, openness, transparency, authority based on merit, scientific integrity, and an appreciation for creative and unusual ideas and have an intentionality about where and how we make investments.

Dr. SCHMIDT. The United States got to where we are because of a unique combination of government, academia, private-sector collaboration in the open community and culture that Dr. Souvaine just talked about. We need to strengthen those links between Federal agencies, the military, private-sector, academics in all sorts of ways, whether it's the FFRDCs (Federally Funded Research and Development Centers) that are used as part of the military process, other kinds of interesting funding that comes to the NSF, DARPA, and so forth and so on. So I think the general answer is more of what we're doing at a global scale.

We have the talent. People want to come to our country. People are incredibly creative here, and we have a strong challenger in China, which runs under a different system that we don't like.

Dr. ABDALLAH. I believe our model worked extremely well and continues to work well, but an alignment of the incentives and alignment in the policies, alignment in the reporting I think will actually benefit us at this stage. Sharing data, sharing research data is important, but we have different ways right now, different agencies, different policies, different reporting requirements. Something like that, improvement in that aspect will help tremendously.

I think also encouraging the incentives to try to get the research out of the universities. Even the basic research that we do at the universities in many cases is leading to ideas that may not be today implementable or has economic impacts, but it will need support, you know, between the lab and getting a large company or an investor to go in there. Facilitating that or encouraging policies to do that I think would be extremely important.

Most importantly, I think investing in infrastructure I think is key, and in many cases some of the startups that we have in Atlanta, for example, they cannot afford to have the facilities that we may have at the universities, but also those facilities sometimes are not equipped to handle the requests from these companies.

Mr. LUCAS. As you heard me say in my opening comments, I am a supporter of doubling the money that we spend on federally funded basic research in the next decade. Part of the challenge that we have here in Congress is not only convincing the majority of each other of the importance of this but convincing those American taxpayers back home that this is fundamentally in their best interest. So thank you for being here today to help make that case.

Chairwoman JOHNSON. Thank you very much. I love your statement. Mr. Bera.

Mr. BERA. Thank you, Madam Chairwoman. You know, we talk about the competition between America and China and the rest of the world. We do have some natural advantages that, you know, I think Dr. Schmidt, as you said, we are a free and open society. We are a society that's based on the rule of law. And, you know, you travel anywhere in this world, people still want to come to

America. And there are some simple things that we could do through policy that actually give us a competitive advantage that we have done in the past.

If I think about my own family's story, my parents immigrated in the 1950s from India to go to college at USC to get their graduate degree. And they were lucky enough to get a visa to stay in this country. And, you know, Dr. Abdallah, you talked about the number of students that are coming here, getting their college training, getting their graduate degrees and their Ph.D.s, yet a lot of those students are having a difficult time staying in the United States. And these are the next generation of entrepreneurs. That is something that is eminently within the possibility of this body to fix, to allow those folks to start their companies here, to stay here.

You know, I don't remember the exact percentage, but a large number of the entrepreneurs and the startups are started by immigrants. It is good for our economy. It creates a ton of jobs. That was one of your six points, Dr. Schmidt as well and, you know, invest in that talent and allow them to stay here.

I absolutely agree with the Ranking Member. We do have to double our investment in R&D. You know, I'm not smart enough to be an engineer, I went to medical school. But a lot of the Ph.D.s that I trained with, you know, that was a talent pool. But I talk to those Ph.D. students today. You know, many of them were going to stay in academia. A lot of them now are going to get their training and go out and join the private sector. That's not a bad thing, and maybe this is a question for Dr. Schmidt.

When academia has unique talents and resources, how do we do technology transfer a little bit better? How do we allow the private sector to partner with the academic sector? Because there's also resources that the private sector can do. And, you know, I think there's some technical changes that we could do through policy through perhaps the tax code to make it a little bit easier for the private sector to partner with research and academia.

And maybe, Dr. Abdallah, you could talk about some of what Georgia Tech is doing in that space.

Dr. SCHMIDT. So half of the Silicon Valley startups are started by immigrants. And so everything you said is correct in the economic terms. The state-of-the-art is for technology companies to work very closely with universities, literally seamlessly. Much of this was done in the biology space where they created joint ventures and so forth, and they actually control the IP. But pretty much everybody's figured out that you want to be next to a leading university. You want the students going back and forth. And you want as a company, you want to give that university money in the appropriate ways because the university doesn't have enough money from its other sources. And I think that's a sustainable model.

Mr. BERA. Dr. Abdallah, and maybe some examples with Georgia Tech?

Dr. ABDALLAH. Yes. Thank you for that question. Actually, as you heard, in my capacity as VPR I'm also responsible for the economic development and the innovation. We have a lot of activities with the companies, both large companies who created innovation cen-

ters on campus, as well as opportunities for small companies and startup to start either from within Georgia Tech or from anywhere to be supported there. So we have programs and activities in that space.

I think there are a couple of things to keep in mind and to help us with. One is companies, as you just heard from Dr. Schmidt, they want to be close to research universities or to universities both because of the talent pool, as well as to get the IP and the results of the funding or the research that comes out of those. But that transfer being close, you know, physically located or co-located with other companies and other entities that are engaged maybe sometimes competitively in the same businesses is very good.

There's one aspect that I think we can maybe work toward that we're discussing at Georgia Tech and other places. In areas such as AI, you know, universities cannot afford to pay what Wall Street and what the top technological companies are offering, so—and in many cases we have faculty members who will leave, take a leave of absence to go to some of these companies and, you know, ask for 1 year, which is fine, and then try to extend it. That puts the universities in a very, very awkward situation. We want them to stay, we want them to engage with the companies where, by the way, the companies have a lot of the data that is needed to do the research also. It's not simply the money. So models that will allow that relationship to be two ways versus basically for the companies to hire away from the universities and eating the seed corn of the future researchers would be very, very appreciated.

Mr. BERA. Great. Thanks. My time's expired. I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Brooks.

Mr. BROOKS. Thank you, Madam Chair. My comments and questions are directed primarily at Dr. Schmidt, but if there is time remaining after he responds and, Dr. Souvaine or Dr. Abdallah, feel free to join in as you wish.

I'm looking at Dr. Schmidt's written testimony, and I'm going to read some quotes from it. Quote, "The United States now faces an economic and military competitor in China that is aggressively trying to close our lead in emerging technologies." Quote, "China's well-documented espionage, intellectual property theft, and talent recruitment programs are disadvantaging our companies, our universities, and our military. The findings of a recent Senate investigation into China's methods to unfairly exploit United States taxpayer-funded research for its own benefit is a case in point."

Quote, "My concern is that China tries to fulfill a vision of high-tech authoritarianism that governing model will appeal to other governments searching for a foundation on which to exercise their power." And when I think of that high-tech authoritarianism, I can't think—I can help think of George Orwell *1984, Fahrenheit 451, Animal Farm,* and others. Then, Dr. Schmidt, you go on to add, "We should not only compete with China but also work with them."

Now, as I think of all your comments put together—and I serve on the Armed Services Committee, and we have plenty of briefings, classified and unclassified. I can't go into the classified part, but the gist of it is that China seeks to manage America's decline. And so there is a significant long-term risk there. Certainly their mili-

tary prowess is increasing. The challenges associated with their claims to the South China Sea are troubling for that region of the world.

And to make matters even worse, the United States-Chinese trade deficit, China is the worst trading partner we have. Our trade deficit there is about 6 times worse as the second-worst country on the planet.

So now to the questions. How do we protect United States' interests with respect to this technology? That's part of it. And can you share some examples, as much as you can in this open setting of where you think there are opportunities to cooperate that would benefit the United States and areas where we should not cooperate for economic and security reasons?

Dr. SCHMIDT. So thank you for that. So you have to have a—the competition with China is going to be the defining competition for the next 10 or 20 years. And the peaceful rise of China is in our interest for obvious reasons. So it seems to me that we have to come with a language and a way of dealing with them.

So the first is I would like us to agree that America should win, and winning is defined as defining the key technologies, inventing the future, driving the technology stack, and all that kind of stuff. To the degree that Chinese technology or technologists can enable us to win on our terms I'm OK with it but not unless it's consistent with that.

So there are plenty of examples where you could imagine if Chinese technology were to dominate the globe with non-American values, it would really hurt us. The most obvious would be imagine if the internet were invented by China with a complete surveillance architecture? Just imagine if we inherited that from China, how different our experience as Americans would be today. So it's really important that we get these underlying technology platforms of which the internet is an example that we have so far won at, to be popular and be successful globally.

One way to think about China is that they have solved the problem of identity, mobile phone, electronic payment, and surveillance in a single device. And my Chinese friends never use cash. But of course everything they do is tracked. And this is very un-American.

Now, imagine if that structure becomes the standard structure in all of the BRI countries, the Belt and Road Initiative countries, of which there's roughly 63. That becomes a huge, huge problem for us. It's a market we can't sell into. It strengthens their leadership and so forth and so on. We don't have good answers as a country for this.

Mr. BROOKS. Dr. Abdallah or Dr. Souvaine, in the time that remains, would you all like to add any additional comment?

Dr. SOUVAINE. I'd say briefly, certainly we need heightened vigilance as the information yesterday about the arrest of the prominent Harvard chemist suggests. Looking at conflict of commitment, conflict of interest, and we need partnerships between the Federal Government and the universities to do that.

At the same time, as we think about competing with China, first of all, it's not just China but it's certainly a lot of it there. But we compete by being the best version of ourselves. We need to recognize and respect that China and other nations contribute to hu-

manity's knowledge, and it's a good thing. We also know from the S&E 2020 report that our researchers across this country are publishing many more collaborative papers collaborating with international collaborators, and the single country that we collaborate with the most is also China.

So we need to understand that that's important, but we need to be the best versions of ourselves. We need to promote openness while recognizing the balance between collaboration and security. We need to embrace competition, discovery, openness, fairness, immigration, international collaboration, curiosity-driven research, public education at all levels, our government-university-business ecosystem, but really do what Dr. Schmidt says. We need to be promoting our values because we're at the table. We're investing. We're part of every discussion, and we continue to promote our version of what it means to be honest, open, transparent, and successful.

Mr. BROOKS. Thank you, Madam Chair. Thank you, witnesses.

Chairwoman JOHNSON. Thank you very much. Ms. Stevens.

Ms. STEVENS. Thank you so much, Madam Chair.

And as Mr. Lucas referenced his disposition in this Congress, I'll say being in the majority and doing things on our terms certainly feels good, and so I will also second your comments, Dr. Schmidt, that as we look to the race of the future and winning the innovation future, the reason why it is so important for us to talk about it being on American terms is because then we set the stage. It is our jobs, it is our transparency, it is our technological might.

But the headlines are also quite alarming over the last several years. In 2017, *The Atlantic* monthly, coming out of the President's budget proposal, had a headline that we are bracing for a lost generation in scientific advancement and research funding. As by comparison looking at our friends overseas, the U.K. just doubled their funding for R&D. South Korea has made a similar commitment, even our partners from the north without question.

So what we're also talking about is sort of a dialog, a social dialog here in Congress and with our constituents back home. But most simply, you know, Dr. Schmidt and Dr. Abdallah, in terms of the work that you do, how much is your current work dependent on basic research funding from the United States Government?

Dr. ABDALLAH. In my day job basically my job is to facilitate the work that everyone else is doing, so I would say at the university probably more than 80 percent is depending on the basic research, including things that are happening at GTRI, which is the applied research arm. But even in that sense we're depending on things that either were developed earlier or are being developed elsewhere.

Ms. STEVENS. And if that basic research funding, sir, was to dry up—not that that's what's being proposed—would there be any alternative?

Dr. ABDALLAH. Not if the Federal Government is not priming the pump and funding that. I don't see any alternative, no.

Ms. STEVENS. And, Dr. Schmidt, I know you're not here in your previous capacity, but you referenced your work with Google. And if it's correct, Google now is one of the five—I guess it's Alphabet, right—but it's valued as one of the five most high-performing

stocks by market cap. But you traced it back to basic research funding. Could that have happened without basic research funding?

Dr. SCHMIDT. It would not have. And the core reason is that in the American system, the basic research is earlier than corporate research. So the basic research, which is largely government-funded with some philanthropy—and I'm personally trying to do that now—is the seed corn. And everything that has driven American competitiveness and American economics has fundamentally started from that 50 years ago. So your predecessors made these incredibly smart decisions 50 years ago starting with Vannevar Bush and the creation of the ecosystem that we have today post-World War II.

And we seem to have forgotten how fundamental this is. Everyone thinks, oh, my God, you know, I invented this, I invented that. You're standing on the shoulders of giants who were originally funded. Virtually all of Silicon Valley was either DARPA-funded or National Science Foundation-funded or university-funded through that mechanism.

Today, all of the leading technology companies are very integrated with their university counterparts. It's very symbiotic. Let's not screw that up.

Ms. STEVENS. Good point. And, Dr. Souvaine, just from your vantage, are you aware of any other modern industrialized nations that debate the merits of funding basic research in such a way that we have dared to do so here in the United States?

Dr. SOUVAINE. No, I'm not exactly. I would have to look into that more carefully.

Ms. STEVENS. Great. Thank you.

Dr. SOUVAINE. But I would just echo what Dr. Schmidt said. Certainly there are VC (venture capital) capital people who've come to talk to us on the board who talk about the fact that what they're commercializing today they know came from a pie-in-the-sky NSF grant 25 years ago. And they are very concerned that they are still going to have something to commercialize 25 years from now.

Dr. SCHMIDT. Can I just add that the Chinese are doing heavy, heavy government funding in basic research in order to catch up. And when I say heavy, we don't exactly know the number but it's a very, very large number.

Ms. STEVENS. Well, thank you. We'll remember all these points as we head into budget season. And with that, Madam Chair, I yield back the remainder of my time. Thank you.

Chairwoman JOHNSON. Thank you very much. Mr. Babin.

Mr. BABIN. Yes, ma'am. Thank you, Madam Chair. Thank you to the witnesses for being here as well. I appreciate it.

It's critical that we continue to invest in our sciences to promote technological innovations here in America. Our investment and prioritization in this country, science and technology is a determining factor in our global competitiveness. But we must protect our information.

We've even seen the infiltration of Chinese influence in our university systems as recently as a couple of days ago. Just yesterday, I read an article reporting the arrest of the Chairman of Harvard University's Chemistry Department, Dr. Charles Lieber, for lying

about receiving millions of dollars from the Chinese possibly in exchange for cutting-research information. Also, a researcher at Boston University was charged as a Chinese agent and lying about it. It is a distinct problem.

I've introduced a bill that will enable institutions of higher education to protect federally funded research from cyber theft and interference. It's called the *Securing American Research from Cyber Theft Act*, and it will provide a pilot project for a nationwide network of secure computing enclaves for federally funded research in universities.

And with that being said, Dr. Abdallah, the FBI and intelligence agencies have warned Congress about the threat of foreign espionage of U.S. science and technology, particularly on university campuses. How can we best work with law enforcement to address this threat?

Dr. ABDALLAH. Thank you for that question. Actually, the FBI and other U.S. law enforcement agencies have been proactive in discussing with universities, educating us sometimes on some of the things that were happening that either we were not aware of or entities that we were not concerned about at one time. So in the last couple of years I'll say there has been a much more collaborative effort, education from the law enforcement agencies. And in fact some of the news that you're seeing are a byproduct of the universities being much more aware and trying to figure out exactly what these conflicts of interest that used to be focused on only financial conflict of interest, what we can do about them.

Some of the things that I think are happening from our side is we're educating our researchers a lot more about protecting sensitive information. I do want to say also in some of these areas it's not necessarily that piece of information, but that is information in connection with others. There are a lot of connections between some of these areas and so on.

One thing that I think would be very helpful is to reestablish the National Security Higher Education Board. This, as you know, was a board of universities and the government to try to look at some of these concerns and try to set policies in place.

Mr. BABIN. All right. Thank you very much. And I think that's a great idea myself.

Dr. Schmidt, I'm very concerned about moves that China is making on 5G wireless technology, particularly in trying to dominate the global market. I understand that the U.K. just recently chose Huawei for their 5G. What do we need to do to not just compete but to lead in the 5G race?

Dr. SCHMIDT. There's a set of things we have to do. There's plenty of money, but there's no U.S. competitors at the scale that we need. So we need a good 5G solution at a sort of national level for hardware, and we also need something which the telcos don't have enough of, more good mid-band bandwidth. Today, they're working in a technology area called millimeter wave, which is very high performance but has some coverage issues. It's not as good as the mid-band, which everyone else is using.

I have separately and as part of my military work argued that the DOD should share some of its key frequencies with the telcos

in order to enable this. I believe that the United States needs a competitive 5G plan.

Today, the reason these countries are purchasing Huawei is, one, it's cheaper than the competitors; and two, they're getting very cheap money out of China to do so. That then enables China to populate their networks with all of the Chinese principles. How is that OK with us?

Mr. BABIN. It's not OK. OK. Thank you very much. And also, China's investment and development and not on basic research implies that they're building their technological success on the basic research developed in the United States and around the world. What is the right balance for protecting U.S. basic research while continuing to promote an open-science system that has made our scientific enterprise the best in the world, Dr. Schmidt?

Dr. SCHMIDT. First place, the stuff that you're describing where those are illegal activities, they need to be aggressively policed. Those are violations of our law and they're not OK. You can imagine a number of ways of strengthening those, more disclosures, things like that, things that you have talked about in your security bill.

To me, the way we win is we run faster. We invent ahead. We benefit from the American model, and we just run faster. I think collectively yourselves and we believe that we can do that. We can win this, but it's a run-faster strategy.

Mr. BABIN. Thank you. And my time is expired. Dr. Souvaine, I had one for you, but I'll have to pass that till later. Thank you, Madam Chair.

Chairwoman JOHNSON. Thank you very much. Dr. Foster.

Mr. FOSTER. Thank you. Doctors—over here, Bill Foster, the physicist and chip designer.

I was fascinated by your comments on what can be called the unified Chinese solution to identity payments, communications, and surveillance. And this is something we're wrestling with on my other Committee, Financial Services, where I'm chairing a task force on AI that, among other things, is looking at identity and all the things there, also as part of a bipartisan push to get the Federal Reserve to consider issuing digital dollars, which of course deals with all those same issues.

And so, first, do you believe there are technological solutions, you know, like, you know, FIDO or federated ID or privacy-preserving biometrics that would allow you actually to solve the problems of identity payments without the surveillance aspect of it?

Dr. SCHMIDT. Technically, yes, for the reasons that you outlined. It's not clear to me that politically that would be acceptable in America. I'll let you guys decide that question. What China has done is it's made access to the internet to be tied to a national ID. There's no anonymous browsing in China. So once you eliminate anonymous browsing, you have a registered ID which you then tie with a face photo. At that point you can track the person not only digitally but also by cameras and so forth so you know physically where they are and you know what they're doing.

The next thing they do is they have a common credit card that they all use, which is essentially government-controlled. And that common credit card, all that data goes into a central processor. So

now we know what the person looks like, where they are, what they're surfing for, and what they're spending money on.

Mr. FOSTER. Right. And we need some element of that to deal with money laundering and ransomware and the long list of things like that. The advantage we have is potentially that we may have a trusted court system that could keep government's hands off of that data, anyway, long discussion not for this Committee, but I'd be fascinated to engage with you separately on that.

As you may or may not be aware, I'm the science guy, but I also started a company that makes most of the theater lighting equipment, and we've been on both sides of patent fights. And when we were engaged in patent fights, I felt at the time that there was a pretty good balance between the rights of patent holders and people that wanted to manufacture stuff. But it's my feeling that things have drifted in a direction where you're off-center, that the system integrators have now—of which you are, you know, involved with one of them, really got too powerful so that you have this doctrine of so-called efficient infringement.

And it's a real problem because if you're going to manufacture a cell phone, you have to license or infringe upon 1,000 patents or something like that. And so you have to have a patent system that deals with that properly. You can't let all 1,000 people hold up your ability to manufacture a cell phone. But on the other hand, you know, there's a lot of feeling, including by me, that we've actually weakened the system too far.

And now that you're no longer associated with a dominant system integrator, I was wondering if you would step back and if you think the needle is well-centered at this point? And I just want to put in before I let you speak for a moment that I'm one of the sponsors of the *Stronger Patents Act of 2019*, that's an effort to move the needle back in terms of increasing the power of patent holders over the system integrators.

Dr. SCHMIDT. I'd have to look at it more specifically. This battle has been going on for a very long time, and it's an important issue of rights. My advice would be, let's focus on the prize, and the prize is American competitiveness competing against China in the technology areas that I've identified. Please don't do anything that would slow down our ability to innovate in these spaces. Do everything you can to cause more investment and more innovation.

Mr. FOSTER. Right, but part of that is preserving the rights of the patent holder. If you come up with a good idea and then get no renumeration because someone stole it. I mean, you're aware of the situation with Huawei and Cisco, right?

Dr. SCHMIDT. I am.

Mr. FOSTER. You know, if China had a functional patent system and a court system, Huawei would be a wholly owned subsidiary of Cisco. You know, it really would be because of the intellectual property theft. But they didn't certainly at the time. And so, you know, we have to get this balance right to optimize investment. And it's a deep question. If you can have a look at the *Stronger Patents Act of 2019* and see if you agree with its goals.

Let's see. And, actually, Dr. Abdallah, do you have any comments on how the patent system is working from your point of view?

Dr. ABDALLAH. From the university point of view, you know, we consider that as a byproduct of the Federal funds, meaning we don't expect to generate a lot of money out of it. You know, most people think that universities or these ideas coming out are making the universities rich. In fact, we support it, you know, more than we get out of it. So anything that would make it more efficient and beneficial for the ultimate goal I am very much in support of.

Mr. FOSTER. All right. Thank you, and yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Baird.

Mr. BAIRD. Thank you, Madam Chair. And this question is going to go to all of you. And I appreciate your expertise and being here as a witness, but the *Securing Leadership in Science and Technology Act*, which I'm an original cosponsor, really prioritizes investing in pipelines for the American STEM workers. And that ranges, as you well know, from skilled technical workforce to cybersecurity professionals to Ph.D.s in areas of need like AI and quantum. And so as, a Ph.D., I understand the importance of research and particularly the STEM-related fields.

So my question to you is, can you comment on the national and economic security risks of failing to develop a domestic STEM-capable workforce? Start with you, Dr. Souvaine.

Dr. SOUVAINE. I think when we look at the S&E indicators that came out 2 weeks ago, we can see that if you look at overall the amount of dependence we have had and continue to have on foreign-born talent and yet if you look between 2015 and 2017, you can see that there's a little bit of a dip in terms of foreign talent coming into our programs. At the same time if you look at the report, you can see that the performance of the United States for, say, eighth-grade students in math and science is mediocre relative to the rest of the world.

That suggests a couple things. One, we need to continue to rely on foreign talent in the medium and the short term. In fact, we will always want to be attracting the brightest and the best, as Dr. Schmidt has said. At the same time, it is critical, it's urgent, it's now we need to figure out how to make the pathways there for every American, every ZIP Code, every background to find the pathways to be successful in STEM at whatever level, whether it's being the skilledworker that help keep LIGO going that needs so much more STEM know-how than an HVAC (heating, ventilation, and air conditioning) worker needed 25 years ago, but we wouldn't have made the discoveries of LIGO without that person.

But what are we going to do? We need to recognize us because of computer scientists, the creativity, critical thinking, communication, perseverance, all sorts of things go into it. And there are multiple pathways to get there. It's not a tower. And because someone has taken a certain number of courses and is successfully this way doesn't mean they can't participate in the STEM economy. We need to have multiple pathways, multiple pipelines. And we need to get on it now.

Dr. ABDALLAH. I myself came here to study, came to the United States to study. There is a benefit to keep that door open. One is others have already paid for that first 13, 14 years of their studies. And they come from a diverse and different background, so they bring with them also other ideas.

The demographics of our U.S. college students also is key because we're not graduating enough students to feed the pipeline also. So there is a lot of work to be done there to get our U.S. students both educated and prepared to come to college. And the best opportunity or the largest opportunity is where we haven't made a lot of headway, and that is in the underrepresented populations. You know, so that's where the opportunity is.

There's one thing I want to comment also on, and it goes across all of these points that we've been discussing, and that is we're focusing on the competition and our competitors with China, but we're not alone. We have allies. We have people we work with in other countries who share our values. And I think keeping that relationship in science and technology and basic research is extremely important.

Mr. BAIRD. I'm close to running out of time, so thank you, and I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Casten.

Mr. CASTEN. Thank you, Madam Chair, and thank you all so much for coming.

I want to echo, all of you have made the comment that, you know, so much of our STEM workforce is foreign-born, and all of you I think have in some fashion raised concerns about are we—do those foreign-born, U.S.-trained engineers choose to stay here or go elsewhere?

I want to focus on a different concern I have that I think we are in many ways keeping them out in the first place. I'm a chemical engineer by training. I went to Dartmouth for my master's degree, did my research on cellulosic biofuels because I really wanted to be a Member of Congress one day, and served for 10 years on their Corporate Collaboration Council, which essentially was alumni trying to make sure the degree program remained professionally relevant.

In the first 2 years of the Trump Administration with the Muslim ban, with the rhetoric coming out, we saw 30 percent and then 30 percent again declines in applications of foreign students to the program. Now, our matriculation rate stayed fairly high, you know, thanks to the hard work of the Administration, but obviously you start to get into real concerns of can you maintain the same caliber of institution with a smaller application pool?

I'd like to submit for the record—I ask unanimous consent if I could an ICEF Monitor story that came out in April 2019, which says that over the most recent 2 years we have seen steady declines in the number of foreign-born students on active student visas in the U.S., suggesting that is not just our singular experience up in New Hampshire.

So my first question is just a simple one for all of you. We've all agreed and I think on a bipartisan basis that we should double U.S. R&D budgets. Can we effectively spend those R&D dollars and get the most out of that research if we're not allowing talented foreigners to participate?

Dr. SOUVAINE. We need to make this country a magnet for people all over the world, for foreign-born talent and for domestic talent, to come here and to contribute to the innovation that happens here and our economy and our security and around the world. So we

need to be open and accessible. And we can entice more people. And it's more competitive right now. As other countries enhance their own portfolios, globally mobile talent has more options of where to go. We need to be the place that they want to be.

Mr. CASTEN. I'm taking that as you'd agree. I mean, I'm assuming—and please chime in if any of you think that keeping foreigners out is a good way to maximize our research spending. I'll take that as a no.

Do any of you believe that the decline in foreign students studying in the United States reflects a decline on the part of the desire of foreign students to come study in the U.S., would you share my view that this is a just declining numbers of visas available?

Dr. SOUVAINE. I think there are more options and there are more countries that are providing resources. We need to make sure that we have the research infrastructure that means that they can come here and do the research that they want to do. We need to have the funding and the pathways certainly with visas and the ability to stay here. So I think we need to do our work.

Dr. SCHMIDT. Pretty much every country has figured out that leadership in our area that we're discussing, especially in AI, is going to be part of national competitiveness, national security, and economic things. All of them have programs to try to keep their people from leaving and coming to the United States. So there is an issue that talent is becoming more globally competitive. The good news is the American model remains very attractive.

Mr. CASTEN. OK. Dr. Abdallah, if I could close with you. I think that if we tell the best and the brightest around the world that we don't want you here, it's a good way to make sure we don't attract the best and the brightest to our shores.

You mentioned in your testimony the one consequence of U.S. research efforts falling behind the rest of the world is that our country will be less able to attract the best and brightest minds from abroad. Would you say then that our failure to create a fair immigration system could cause damage that would be harder to repair down the road? And when we get beyond our current xenophobic era, what should we do to restore some of that credibility?

Dr. ABDALLAH. I think, as you just heard, we want to continue to be a magnet. And if we are, if we open our applications and if we make it so that the work that we're doing in here and we invest into our science and technology, then they will come. The reason today—one of the reasons why everybody else is copying our model is because it was working. And when we changed our model, then I think it becomes a lot less attractive. I think the best and the brightest want to go to where they're welcome but also where they can do their best work. And I think that's what we need to continue to do.

Mr. CASTEN. Thank you. I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Balderson.

Mr. BALDERSON. Thank you, Madam Chair, and thank you, panel, for being here this morning.

Two questions, two-part question. Dr. Souvaine, I'll ask you first. As the Chair of the National Science Board, can you comment on how the National Science Foundation is working with private industry and what more you think needs to be done to encourage

those partnerships and the impact that we can expect from the greater involvement?

Dr. SOUVAINE. I think at the current time there's more partnership that is happening between the Foundation and industry. And certainly with the proposal that was discussed earlier about incentivizing NSF to do more with translation, that helps make it more possible.

I think also in light of a question that happened earlier, I think that there are sometimes impediments to partnerships being kicked off. There are one-off relationships that have to be created. And I know right now there's work being done looking at the *Bayh-Dole Act*. I believe NIST is chairing and NSTC (National Science and Technology Council) is convening and kicking off some discussions and they issued a paper I think a few months ago about ways to accelerate partnerships and have to remove any barriers.

But I think clearly right now it's going to be key to accelerate the partnerships among government agencies, industry, and the universities and make sure that we make the system frictionless. We accelerate our innovation as quickly as we can.

Mr. BALDERSON. And I agree with that. Dr. Schmidt, what can Congress do to further support the government-industry-academia research relationship?

Dr. SCHMIDT. I outline some of the comments in my report. I think there are some mechanism changes as to how funding occurs to be a little bit more flexible. I think we would probably all agree with that. More money is obviously important. More shared facilities. I highlighted, for example, research cloud, other things like that is sort of a reasonably obvious list of infrastructure that would help both industry, private, and cause things to occur faster. All of the issues around talent that were previously discussed, all the focus on STEM also helps.

But I think if you think about it, it's a small group. What do they need? They need a few more people, they need to rush fast, they need some infrastructure. This is not relatively expensive compared to like cyclotrons. And off they go. That's the American model of creativity, and it's extraordinarily valuable. Seventeen of the top 20 research universities in the world are Americans today. This is a crown jewel of our country.

Mr. BALDERSON. You brought up the financial piece, and that was my second part of the question. How can we use these partnerships to overcome some of these financial barriers? Any thoughts or suggestions? And anybody on the panel can answer that also.

Dr. SCHMIDT. Well, in general, the government is complicated to spend and partner money with for many, many reasons. And I think having relatively simple ways for light partnerships where people say, look we're going to work together on this where it's clear where the intellectual property goes is probably a simplification that would be helpful.

Dr. ABDALLAH. I think supporting infrastructure, you know, which sometimes is costly. You know, it's not as costly as what Dr. Schmidt mentioned in some cases, but that would be one area.

I think collaboration with the national laboratories, too, is key in this space. You know, we have also another piece of this research ecosystem, a lot of work that's being done at the national labora-

tories both for national security, national defense, but also for other areas and collaborating with universities and companies there is important.

You know, in order to create disruptive innovations, sometimes what we really need is consistency in funding and clarity in regulations. A lot of times, you know, if we have that, then we can let the imagination of the researchers and so on go. So it is extremely important to have the funding for the basic research. I think a lot of times it is in the policy domain that I think we can use a lot of help.

Mr. BALDERSON. OK. Thank you. Dr. Souvaine?

Dr. SOUVAINE. To just go back to your question about NSF and partnering with industry, one recent highlight is that the CISE (Computer and Information Science and Engineering) Directorate and the Social, Behavioral, and Economic Sciences Directorate are partnering with Amazon jointly to support research that's focused on fairness in AI with a goal of contributing to trustworthy AI systems that are readily accepted and deployed to tackle grand challenges facing society.

There are other partnerships that they have recently created with Google and Boeing, again, to capitalize on areas of research that are of interest to both parties but to reiterate that each one takes a lot of startup time to get going because of various pieces of friction that make it possible.

Mr. BALDERSON. Thank you very much. Madam Chair, I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Beyer.

Mr. BEYER. Thank you, Madam Chair. I was fascinated by Dr. Schmidt's opening thoughts on doubling the Federal R&D budget, and I've heard this from all of you. We see from the paperwork that was 0.7 percent last year and 1.6 to 1.9 percent in 1960, so basically, you know, 40 percent, 35 percent. Should we look at this as a long-term commitment to a specific percentage of GDP or specific percentage of the Federal budget rather than simply doubling the dollars that we have right now? And in doing that, how best do we do that, structuring through a commitment from the Budget Committee or a resolution of Congress saying we commit, for example, the 2 percent of GDP for Federal R&D?

Dr. SCHMIDT. These things are ultimately a consensus at the national level. And we are well below the numbers that got us to where we are now using any set of metrics. So what happened with Sputnik was the national challenge, which was seen as a national security challenge, boosted that. So we face something which is analogous but different, the challenge of a globally focused competitor in China. And if that's the necessary reasoning to get us back onto a 2 percent number, I'm supportive of it.

Mr. BEYER. My friend Mr. Casten talked very well about the impact of not having a sensible immigration policy on the stay rates and the number of people applying. For years, politicians from both parties have talked about the *STAPLE Act*, that when you get, you know, a higher degree, we staple the green card to it. It never seems to go anywhere.

Maybe, Dr. Souvaine, do you have any insight on why we don't make progress on this?

Dr. SOUVAINE. I don't know, but I certainly would like to. I think that we have extremely talented people who come and complete degrees here and want to stay, and it would be great to make the pathways smoother for them to do so and to contribute to our society.

Mr. BEYER. Great. Dr. Schmidt?

Dr. SCHMIDT. So I've spent more than 2 decades in Congress talking about this particular issue, and what my friends on both sides say is that this is an important issue but it gets caught up in other and broader political issues. So I would encourage you all to think about these are a relatively small number of very specialized skills. They're tied to national security and the strength of our Nation. Anything that we can do for the purposes of this issue to address it as it's in our interest for national security, it causes America to grow fast, to create companies, and so forth I think would be helpful.

Mr. BEYER. My friend Dr. Foster talked about how if China had the same patent protections, Cisco would own Huawei. And yet, Dr. Schmidt, you talked about the dilemma, the absolute necessity for us to develop our own 5G competitor. I'm sure the private-sector folks, the Verizons, et cetera, are doing that right now, but how best do we as a Federal Government stimulate and make plausible a global competitor to Huawei?

Dr. SCHMIDT. The reason this is so important is that in 3G the Europeans led. And through American ingenuity, we became the leaders through our telco leadership in 4G LTE. As a result, much of the infrastructure was American-made. The chips were American-made. The software was American-made. And we benefited enormously from early applications on that. So a whole bunch of my friends and myself feel very strongly that we need a national program around 5G, which enables the telcos to get the bandwidth that they need. There's plenty of financing if these things work out, and most of its related to access to the right bandwidth.

Mr. BEYER. Good. Dr. Souvaine, did you have anything to add?

Dr. SOUVAINE. I think the most recent Science and Engineering Indicators Report has a lot of information about patenting. And one of the questions I find myself asking myself as I look at it is the question about patenting in the U.S. and patenting in the other countries. And I have a feeling that sometimes we patent things in the U.S. and we don't patent things in the other countries, and that leads to some of the problems that we get into. And I think that a longer look at patenting worldwide would be a good thing for us to do at some point.

Mr. BEYER. OK. Madam Chair, I yield back.

[Audio malfunction in hearing room.]

Mr. WEBER. As Americans, we should all be proud in my opinion of the DOE's incredible accomplishments. But, as you say, China is in the process of catching up. In your opinion, Dr. Schmidt, what would it mean for U.S. leadership in science and technology should China pull ahead of our exascale efforts and our high-performance computing efforts in general?

Dr. SCHMIDT. So high-performance computing in general, of which exascale computing is an example, is crucial for energy and also for national security, especially nuclear. Much of this research

has enabled our nuclear leadership and our defense posture—and again, there's much classified work on this.

China has focused on what you have called exascale computing for more than a decade, and there have been a number of times when their computers have been significantly faster than ours. Again, it's a race. So once you understand it's a race, we have to win this, and we have to continue to win it. If we stopped this, we would stop being able to model both the national security aspects of this, as well as new innovations in renewable energy, traditional energy, new materials. There are so many things that are related to the computation that the DOE's funding. I cannot emphasize this enough.

Mr. WEBER. Right, especially the new materials. And I'm glad to hear you say nuclear as well. Our bill, the *Securing American Leadership in Science and Technology Act*, would authorize critical investments in DOE's advanced scientific computing programs. It would more than double funding for the Department's activities in that area by the year 2029. In your opinion, in what ways can we facilitate collaboration with American industry—and you came from industry, right—to maximize our return on this investment? How do we do that?

Dr. SCHMIDT. Well, much of that is going to happen through the President's initiatives to modernize the nuclear infrastructure, which I'm familiar with and I'm sure you are as well, and so I think focusing on getting that right.

The newest strategy in manufacturing is called basically digital twinning. And what you do is you build a computer model that's a digital simulation of the physical thing you're building. Changing the way we build things—and I'm talking about at a national security level, as well as in the commercial sector so that we can simulate them using these powerful computing resources that you're describing—allows us to have more reliable outcomes, more predictable outcomes when we actually build them. This is crucial in the nuclear area because we can't test these things because of all sorts of treaties.

Mr. WEBER. Yes, thank you for that. And I recognize in your—I think it was discussion with Dr. Babin you all talked about the 5G network. I think you said something to the effect that we don't have a competitor and actor large enough to do this. Is that what you said?

Dr. SCHMIDT. The primary suppliers are Ericsson, Nokia, and Samsung. And I would love to see an American set of startups, U.S. startups. There's plenty of interesting ideas that could come. And I think the easiest way for that to happen is to say to them there's going to be lots of spectrum, there's going to be lots of competitors. The 5G revolution is coming, and it's going to be led in America and not in China.

Mr. WEBER. So you're saying there's going to be lots of spectrum. You may or may not be aware that the FCC (Federal Communications Commission) has talked about auctioning off some bandwidth. Are you familiar with that?

Dr. SCHMIDT. I am, and have spent a lot of time on this.

Mr. WEBER. The highway departments have raised an issue about that. What can you tell us from your perspective about that?

Dr. SCHMIDT. So there's a technology that's been around for about 10 years called sharing. And as scientists we believe that the various objections can be addressed by sharing the technology where the government has priority. And this technology is relatively new and we think very powerful.

Mr. WEBER. So if they sell off or auction off part of the spectrum, does that mean less spectrum available for competition?

Dr. SCHMIDT. Well, the government has for the last 20 years been auctioning spectrum as a property right. That's essentially selling the highway to the truck operators. It would be better to have the highway be shared among the truck operators and the car operators and so forth. And we think technologically sharing is the future.

Mr. WEBER. OK. Thank you for that. Madam Chair, I yield back.

Chairwoman JOHNSON. Thank you very much. Ms. Bonamici.

Ms. BONAMICI. Thank you to the Chair and Ranking Member, and thank you to the witnesses for your expertise. I'm glad to see so many people here today interested in this topic.

I know the title of this hearing is "Losing Ground: U.S. Competitiveness in Critical Technologies." I want to start on a positive note. We do have some of the best scientists and researchers, programmers, engineers in the world. We've seen tremendous progress in the development and deployment of high-performance computing.

I want to follow up on Mr. Weber's discussion. In northwest Oregon, where I'm honored to represent Intel, recently unveiled its Horse Ridge chip processor to accelerate the testing and potential of quantum computing. These kinds of technological advancements can be used for energy exploration, predicting climate and weather, predictive and preventive medicine, emergency response, and more.

Last Congress, we passed the *National Quantum Initiative Act* to strengthen research and development into quantum computing and maintain U.S. leadership. The bill established a National Quantum Initiative Advisory Committee to advise the work on this Committee. These investments are needed to meet increasing demands and emerging technological changes, but as the witnesses demonstrated in their testimony today, we still have more work to do, especially to keep pace with our international competitors.

Dr. Schmidt, in your testimony you noted that China has almost twice as many supercomputers as the United States. You suggested there is need to recalibrate areas of competition and cooperation. So what Federal policies would be needed? But also are there additional policy provisions that this Committee should consider now that the *National Quantum Initiative Act* has been passed and enacted?

Dr. SCHMIDT. So, first place, the *National Quantum Initiative* is a fantastic piece of work on your part and is very, very helpful. It's going to need more. It's going to need more money, more focus, and so forth as it develops, but these things develop at a certain level. I think in general I would simply refer to the testimony of all three of us, that as a policy level it's more resources, more flexibility, more focus on the basic research side, consistent with national security, understanding that urgency is important. I think my personal view is that the formula works really well, and I just want

it to happen faster. And as the students come out and the faculty members come out and the ideas come out, the brilliance of the American innovation model in terms of creating companies will be competitive.

And if I can just hammer on the Chinese thing, the Chinese have a system called 9–9–6. They work from 9 in the morning to 9 at night 6 days a week, right? That's what we're dealing with. We need to be on that footing.

Ms. BONAMICI. Appreciate that. Dr. Souvaine, your testimony highlighted the need for a Federal strategy for basic research investments that considers national needs and competitive opportunities and lays the groundwork for future discoveries. So the Committee is also well aware that Federal support for science research and development has remained relatively flat since 2000. So what level of Federal investment would be needed in our research facilities and infrastructure? And beyond increasing Federal investments, what should our Federal strategy on basic research include?

Dr. SOUVAINE. It's tricky saying what an exact level would be. And certainly one of the Congresspeople cited the range that we've gone to from back in the 1960s between 1.6 and 1.9 percent of the GDP was being spent on research and development and now it's more like .6 or .7 in terms of the Federal R&D spending. The NSB does not have a position on a specific dollar amount for R&D spending. What we can say is we can also look and say that the total R&D spending in the country is at an historic high of 2.8 percent because the business sector has stepped up and is being investing a lot more in R&D. At the same time we need to realize that when the business sector does that, there's a different kind of R&D in general that's being supported than what the Federal Government can do.

Ms. BONAMICI. Right. And I just want to call out what seems to be a bipartisan agreement that we need more funding, which is helpful. I want to try to squeeze in one more question here or comment. I want to align myself with the comments of my colleagues who talked about the importance of immigration reform. And I know that looking at the workforce in northwest Oregon. But I also want to talk about the importance of growing our own talent here.

And, Dr. Schmidt, you talked about talent development, including K–12.

Dr. Abdallah, you had that wonderful Martin Luther King Jr. quote about the purpose of education, to teach one to think intensively and to think critically. That's really important.

Dr. Souvaine, you had a comment as well about creativity, problem-solving.

I serve on the Education and Labor Committee, and I know and have worked for and advocated for well-rounded education, K–12. Dr. Abdallah, you said the civics and humanities, I'm the Founder and Co-Chair of the STEAM Caucus to integrate the arts. Arts education helps boost creativity. It helps people develop innovative, creative problem-solving minds. And we found that students who participate in the arts are more likely to participate in things like math and science fairs, for example.

So that's just my call out as we talk about these issues and developing our own talent here, the arts are not a frill. They actually

help people to learn—the brain research is to learn creatively and critically. And other countries are beginning to be ahead of us in that. I just wanted to make that point.

I'm out of time, but we can follow up at another time. Thank you, and I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Gonzalez.

Mr. GONZALEZ. Thank you, Madam Chair and Ranking Member Lucas, for holding this very important hearing. Thank you to our panel today.

Dr. Schmidt, as a GSB grad, it's nice to see you here. I didn't have the pleasure of having you in class, but very good to see you here.

I want to start on the talent side. So I've run a startup before in Silicon Valley trying to find talent, and the talent shortage and competing with an Alphabet as a little itty-bitty startup and trying to compete with all that can be offered is very challenging. And it shows you just the scope of the problem. And so I want to echo a lot of the comments around visa reform in particular.

I think there is kind of two ways to look at it. There's the home-grown talent piece, which we all agree we need to invest even more dollars in STEM. There seems to be bipartisan support for that, so chop chop, let's go.

And then the second piece, which I just think is insane, which is we train people, we bring them in, we give them access to our research universities, we spend all kinds of money training them, and then we throw them out of the country, which I just think is nuts. No business would survive that way if that's how they operated. I don't know why we think that's a good practice here. But it's not.

And so I want to start with Dr. Schmidt with this question. Put your business hat back on for a second. When you're dealing with these shortages, what decisions would you make as a company with respect to where to locate talent and hires given the tightness of the labor market here?

Dr. SCHMIDT. So the good news is that the system that we're talking about in the United States is responding to what's going on. Computer science has become the number one major in most of the leading undergraduate universities, which is a shock to me because when I went to college it didn't exist. The graduate programs around AI have thousands of applications. These are within the universities for 50 slots or 100 slots. So we know that the engine is producing the labor, right, and that's a great American story.

Mr. GONZALEZ. Right.

Dr. SCHMIDT. Furthermore, there's plenty of money for AI-based startups to hire these people even at inflated salaries. So I think the system is gearing up for success.

Mr. GONZALEZ. Great. Great to hear. And then staying with you, you talked about how the AI machine learning race is a global one, totally agree. I've been of the perspective for a while we need a multidisciplinary approach and standard-setting as we deal with some interesting ethical dilemmas and tech dilemmas and things like that. Structurally, how would you go about solving sort of the standard-setting challenge to make sure that, as these technologies

develop in China, for example, is playing by a set of rules that are informed by sort of western liberal democracies if you will?

Dr. SCHMIDT. I doubt China is going to want to follow our rules about surveillance——

Mr. GONZALEZ. I sincerely doubt it.

Dr. SCHMIDT [continuing]. And privacy and so forth. There are probably areas where we can collaborate in standards. The most obvious one is AI safety. Let's imagine that an AI system begins to do something that is not expected. That's not in anyone's interest. And so having a discussion about that, especially in a military context, is probably very important.

Mr. GONZALEZ. Yes, so that was actually going to be my next question. So don't comment specifically on this project, but the Project Maven, which at one point Google was involved in and had some controversy inside Google. Palantir may or may not be doing it, if you listen to their CEO's comments.

Talk about on the national security front how important it is to lead on AI machine learning with respect to kinetic warfare because there's clearly going to be a blending of those technologies.

Dr. SCHMIDT. So I'll tell you what I've told the Department of Defense. AI today started as largely a vision revolution. And computers today have better vision than humans. They see deeper, they see more accurately. They don't make those mistakes. So most of the initial use of AI is going to be in vision-related. Which is why in the commercial sector the biggest impact will be in health care and will revolutionize health care, which is an amazing story. In the military, much of the military in peacetime is spending its time watching things, intelligence, and so forth and so on. And you have expertly trained soldiers, airmen, and so forth who are sitting there watching screens all day bored as they could possibly be. We can fix that.

Mr. GONZALEZ. Yes. And, you know, I guess one thing I want to encourage the body on is if we stop, right, if we just say, hey, we are not going to be the Project Mavens of the world, surely China will. And if we see the ground on that type of technology, I think we're putting our national security at risk. And I think that's something we all agree we shouldn't be doing. So with that I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Perlmutter.

Mr. PERLMUTTER. Thank you, Madam Chair. Thank you to our panelists. Dr. Schmidt, I don't know if you remember, a number of years ago you came and spoke to some of us in the Library of Congress. And your topic was similar to today's, just generally how do we maintain such an effective both educational and commercial system.

And so over the last 10, 12 years—and you've used the racing and the running metaphor, I mean, have we been losing ground or falling behind in the race faster and faster or how would you describe it? Because when we talk about a race, there's usually a finish line, OK, but this one, we keep running, Japanese come in or the Russians come in, the Chinese are drafting us and circling around us. In this race just listening to the testimony, it's talent, it's resources, it's incentives, kind of what you've been talking about. In losing ground, are we losing it faster and faster? And in

the talent, resources, incentives kind of categories, what best can we do to get back and pass these guys back up?

Dr. SCHMIDT. So if you look at the last 50 years, America has faced many challenges that have had a technological basis. And we've overcome them in this formula that you described. And I think we should be incredibly proud of that. It's a strength of our country that, you know, it got me to where I am. It got all of us to where we are.

So the question now is you face a new competitor in the form of a large competitor operating in a different way, right? It's moving quickly and has publicly stated their objectives. Well, how does America face that? We don't cower. We don't sit there and say, oh, that's OK. We get our act together and we focus, we create a sense of urgency, and we figure out how to solve problems. Let's solve the problems of getting foreign students in here that we need. Let's solve the problems around 5G. Let's solve the problems around getting the Federal Government to have the technology people that they need. They need these people. The military needs these people. Let's have them work together. There's all sorts of good technological solutions that we can invent together using this.

Mr. PERLMUTTER. Thank you. Dr. Abdallah, any comments?

Dr. ABDALLAH. I agree completely. I want to add something about solving the talent problem, for example. So at Georgia Tech about maybe 7, 8 years ago we were asked to see if we can deliver a quality master's degree in computing at a scale. And initially the conventional wisdom was you cannot do that. Today, I'm proud to say that we actually have 10,000 students who are getting a degree from Georgia Tech and a master's in computing for $7,000 or less, a lot less.

So there are solutions. There are creative solutions. This, by the way, did not come from within Georgia Tech. It came from someone outside of Georgia Tech who came and shopped around. But today we're able to serve or educate about 8 to 9 percent of master's students. So there are these ideas that are emerging from different places, and I think, you know, my hope is that we can connect the ideas together, connect the resources together and facilitate both the flow of policy funding and resources because some of these solutions may be solved better at a small company, some of these problems at a small company versus a large company, at a national lab or across the world with one of our allies in Europe or elsewhere.

Mr. PERLMUTTER. Thank you. Dr. Souvaine?

Dr. SOUVAINE. Actually, I wanted to mention a program at Georgia Tech. At a younger age where there's a middle school program, which is doing a wonderful job at exciting middle schoolers to go into STEM. And, again, if that could be scaled also—I want to see us be able to more quickly share best practices and have them infect the rest of the country. View it like a virus.

There was a wonderful conversation that Dr. Karen Marrongelle, who's the Director of EHR at NSF, had with the Board in November where she talked about best practices about programs that they could prove at NSF with their educational research work. If 4-year-olds to 6-year-olds do this, 5 or 6 years later they're still excited about math and science. But at the end of the project it's proven

to work and it sits on a shelf. How do we generalize, how do we disseminate?

Mr. PERLMUTTER. Thank you. I was going to talk about Libra and Colibra and creating a digital currency by a dominant player in this technology sphere that's taken it all offshore, and I worry about surveillance and I worry about knowing everything. But, Dr. Schmidt, I'll just leave that alone.

Mr. FOSTER [presiding]. Thank you. The gentleman from California, Mr. McNerney, is recognized for 5 minutes.

Mr. MCNERNEY. Well, I thank the Chair. I thank the panelists. This is really informative this morning.

Mr. Schmidt, my district includes Stockton, California, and I'm really proud of Stockton because it's the first city to launch an AI strategy. But it has this history of economic hardship. It's working hard to revitalize and turn that around. *U.S. News & World Report* recently reported that Stockton is the most racially diverse city in the country. And I'm very excited about what's going on out there. But I want to talk a little bit about what the government—the Federal Government should be doing.

But I want to point out and make a plug for my *AI in Government Act*, which will create a center of excellence within the GSA (General Services Administration) to provide resources to the different agencies.

Mr. Schmidt, what steps should the government be taking in your opinion to help address the risks of bias in artificial intelligence systems?

Dr. SCHMIDT. So there's a great deal of concern about AI bias in the community. And the way to understand the problem is that AI today is largely trained from data that's in the real world, so whether it's from language or processes or loan applications or whatever, it's trained from what it has seen. And we know that these systems have biases in them. We're not debating that. So the research that's underway is how do we correct the model when it comes out to limit any unintended bias? This is an issue that pretty much all of the technology companies have identified as a key part of their ethics principles. It's not solved yet.

Mr. MCNERNEY. Is there a role for the Federal Government to solve it?

Dr. SCHMIDT. This is a great opportunity to plug for more research funding in these areas. It's an area of very active research in the universities.

Mr. MCNERNEY. Well, thank you. The AI and cyber threats is also an interesting sort of area. Is that something you're concerned about and how AI can be used to help us defuse cyber threats?

Dr. SCHMIDT. Well, AI will definitely be used to watch—remember, I discussed that AI is a monitoring system that today, a vision. It'll be used for dynamic monitoring. You simply can't monitor everything. And it's reasonable to expect at a national security level that you'll be able to look at all of the things going on, and the AI will say something's up, I can't tell you why, but look over here. It can't tell you why because it doesn't understand, but it said there's an unusual pattern here or there, and that's the state-of-the-art.

Mr. MCNERNEY. Is that deployable in home computers?

Dr. SCHMIDT. You would do this in classified settings I think.

The other thing that is of concern is that there are people who think that the models themselves can be corrupted, in other words, an attacker can take the model and change it after you've trained it in such a way that it doesn't do what you wanted. And that general issue around AI safety is also important.

Mr. MCNERNEY. Well, how do you think the Federal Government can help universities produce AI talent?

Dr. SCHMIDT. Again, I think the universities are fantastic in what they do. They need more funding, more infrastructure along the lines of what everyone has said.

Mr. MCNERNEY. Thank you. Dr. Souvaine, I really appreciate your comment that it can no longer be socially acceptable to be bad at math, but how do we change that? I mean, how do we attack that? Or anyone on the panel that has an answer to that.

Dr. SOUVAINE. It's really complicated because education is done all over the country in local school districts—I mean, there's so many levels—there's local government, there's State government, there's the Federal Government. There's the schools, there's the training of teachers. It's a huge network of educational systems. And yet I was so excited by what I referred to, Karen Marrongelle's presentation at the November Board meeting where they could present actual programs that have done longitudinal studies and shown that if 4-year-olds to 6-year-old do X, and then when they're older they're doing Y, that they are progressing in their understanding.

We need to expand our whole understanding. You know, I think that when I go someplace and someone says I was great at math till 7th grade and then I hit the ceiling, there is a sense that there's a ceiling. And yet people learn this way or that way or the other way. They learn all sorts of different ways, and we have to view it as our charge to empower every citizen to have what they need, and every citizen needs to read and write, and every citizen needs to be comfortable thinking mathematically or computationally. And we can do that.

Anecdotally, I had a degree in both math and English, and I taught 10th grade math and 10th grade English at the same time in a high school. And I found that someone who's really good at English I could use that skill to help them be better at math. And if they were really good at math, I could help them be better at English. That's what the convergence is about, the convergent thinking is about, that the mixture of disciplines we can access the creativity of how we all think, and we can all contribute to the thinking that needs to be happening in the generations that go forward.

Mr. MCNERNEY. For just a second here, in the Bay Area and a little beyond it's kind of cool to be a nerd and a geek, but how do we get that out to the rest of the country? I mean, is Hollywood going to be an important part of this or social media? And if the Chairman will indulge me, I'll let Mr. Schmidt take a shot at this.

Dr. SCHMIDT. I think Big Bang Theory has certainly helped and, you know, television and media matter a lot. As you know, a lot of people are now using the Khan Academy software, which has a very large mathematical component, to supplement their learning.

I think building a movement around parents to say that the math education my kid is getting is not good enough; I'm going to supplement it with all sorts of free services would be helpful.

Mr. MCNERNEY. Thank you. I yield.

Mr. FOSTER. Thank you. And Members are advised if they're interested in another brief round of questions that we'll make a shot at that.

And Representative Lamb from Pennsylvania is now recognized for 5 minutes.

Mr. LAMB. Thank you, Mr. Chairman.

Dr. Souvaine, just to kind of follow a little bit further down that same trajectory, I think the point about middle school and high school is extremely important. Also very challenging for us from the Federal level. And there are those that are more than me about it. But, you know, we've seen a little bit of a flatness in educational attainment and testing in those levels over time.

To me in the short term what's a little bit newer or maybe more promising is the transition to convincing young people that there are other post-high school options besides an immediate 4-year degree and trying to get more people to go down the path of job-training skills, community colleges. And so just having listened to and seen your testimony, what specific institutions do you think are best to steer people toward—you mentioned community colleges specifically. Would you say they are the best? Have you seen apprenticeship programs or other models just kind of quickly? What are the actual places where it's being done well?

Dr. SOUVAINE. We published a report last year on the skilled technical workforce, and we did that after a series of listening sessions. And so there's a number of places that we visited that had NSF ATE (Advanced Technological Education) funding which showed that they were partnerships between the community college, the university, and the industry and the local area. And together they were creating pipelines where students were so excited. They were doing terrific work and going directly into jobs that were paying $80K without a——

Mr. LAMB. Yes, that confirms what we've seen out my way as well. But it seems like the community college is often the best suited to kind of lead that partnership as the deliverer of the training with those partners.

Dr. Abdallah, I thought your example from Georgia of the $7,000 or $9,000 or whatever it was master's degree. Can a major university like yours also offer something like that short of a bachelor degree or is it better done at a kind of smaller institution that you support?

Dr. ABDALLAH. Actually, we do collaborate and cooperate with community colleges and high schools and others to do that. In fact, in Georgia right now there is a bill that passed last year and funded to try to put computer science education earlier and earlier, which I think is also important is to start injecting computing thinking or computer science earlier.

Mr. LAMB. Great. Thank you. Last question, Dr. Schmidt, I think you've addressed pieces of this, and I apologize if I missed some of it. But often when we talk about the comparison with China, we talk about kind of overall dollar amounts. But my sense is from

what you and others have said is there's also a qualitative difference about how we do the R&D here versus there and the ecosystem we have and how we spend the money that we invest. Is there kind of a short way of explaining that, what's different about just the way we do it here in the culture we set up versus how it's being done over there?

Dr. SCHMIDT. Well, you know, 10 years ago people were of the opinion that China would not get to this point. There was a sort of American—if I may say arrogance that somehow we're better than them because of our model. And it looks to me like their model is different. So theirs is heavily government-funded around the programs that I identified in my testimony, which include AI, 5G, finance, and so forth, all areas of critical infrastructure for America as well. But they do it pretty much top-down. It's much more structured, and there's much less, shall we say, individual freedom in pursuit of activities. However, the product is very good and very much a number two today, on its way to being number one in some areas.

The American model can be understood as much more messy, right? It's much more—many different—it's a partnership and so forth. But as Dr. Souvaine said, the model that has worked well for America has been these local collaborations where the government and the local people are solving some problem, in this case, STEM education. That flexibility is more fundamental than it appears because it allows for strategic flexibility. It allows for the businesses to be more flexible. It allows for everything to move quicker.

The Chinese advantage is that they have access to very inexpensive capital from the government, and they also have a culture of Chinese entrepreneurialism and wealth creation that's historic. And so that has driven this enormous internet phenomena inside of China, which is an issue in terms of their own internal politics but is nevertheless impressive.

Mr. LAMB. Thank you very much. Mr. Chair, I yield back.

Mr. FOSTER. Thank you. And I will now recognize myself for 5 minutes for I believe the last set of questions here.

You know, we have been struggling with the immigration problem for, you know, more than a decade. And there was an interesting thing that happened last year where the U.S. House passed with a large bipartisan margin something called the Ag *JOBS Act*, which was essentially comprehensive immigration reform for agriculture workers and their families. And so we had the large number of Democrats and Republicans vote for this, something that in previous years they would have called amnesty.

And so the question that I have is whether there may be a pathway to comprehensive immigration reform that is sector by sector, that along those lines I introduced last year the *Keep STEM Talent Act* that is a rifle shot at the high skill thing. It simply provides permanent resident status to international students who've completed advanced STEM degrees at U.S. educational institutions and are interested in continuing research.

And so I just wanted to highlight that because, you know, we've struggled and failed with comprehensive immigration reform, but I was startled to see the broad support for a single-sector approach

in this. And I think there may be a possibility in the tech sector as well because of the bipartisan support for that.

The other thing I'd like to bring up is of the different models for funding both fundamental and applied research, one of them is to allow the funding agency or the government to retain an equity stake in the startups. For example, Israel sort of famously does that. The Chinese do it implicitly with their state-owned enterprises. And universities retain an equity stake in things that spin-off. And I was wondering if you think there's a merit for us looking into that as a systematic way of not—of increasing the pie? You know, if we had—for example, the government had retained a 5 percent equity stake in Google, that might have made a transformative difference in our ability to fund R&D.

Dr. SCHMIDT. While I acknowledge the point, I will point out that the tax revenues to the government of these companies so far exceeds the value of that 5 percent, so if you think about it, the number of jobs that are created, the economic infrastructure, the sort of positioning of the technology innovation engine—and, by the way, that includes things like fracking, right, in terms of its impact that it had on the Midwest. Over and over again the early money which is seen as a sort of gift can be better understood as an investment for 5 or 10 or 15 years from now for huge wealth creation for the Nation, which the country does get in the form of its tax revenues.

Mr. FOSTER. Dr. Souvaine?

Dr. SOUVAINE. My former capacity as VPR where our tech transfer was one of the portfolios I would say that there was not a lot of return on the patents that we had. But where there was the university's share was used to reinvest in basic research in a way that didn't require the administrative burdens of massive numbers of grant proposals for 3 years, et cetera. And so that in a sense it is serving the Federal Government as it currently is and having the share in the university when it occurs because it is re-ceding something that the government cares about. It cares about the results of basic research.

Mr. FOSTER. Yes. And the patent royalty model for universities is long-standing. Did you have any comments on having a look at, for example, the Israeli model, which is sort of an intermediate.

Dr. ABDALLAH. Well, so most universities do not keep equity in the usual sense. I mean, there are different models, but usually the universities in this space would encourage licensing or trying to help from that point of view.

I do want to say that the Federal dollar does multiple roles. It has multiple roles. It pays for the research. It pays for the education of the students who are also going to go out and create more research and get jobs. And it also potentially spins off these companies. So the investment is—has three different sources eventually of trying to recover or to try to pay back.

As far as the universities are concerned, this is a role that they assumed, you know, gladly assumed to try to commercialize and try to get the research out, but it is not something that pays off in the short term. You know, at a place like Stanford, for example, I think they have three companies that gave back more than $100 million so you think about Stanford as generating all of these companies.

I think overall out of the thousands and thousands and thousands of companies, you know, the very few will get about $1 million. So it's a high-risk place, and I think it's important to keep the model that we have right now.

I'm not sure—I haven't studied the Israeli model or getting equity into that, you know. I'd be happy to have that at Georgia Tech, but I don't——

Mr. FOSTER. Any comments on that for the record. I guess we're out of time here. But, you know, before drawing the hearing to a close, I want to thank the witnesses, though I have to say the most exciting thing that I heard was a statement from my colleague, the Ranking Member Mr. Lucas, that he was strongly in favor of doubling the Federal R&D budget. And so that's got to be the most exciting thing that we've seen here.

And the record will remain open for 2 weeks for additional statements by the Members and for any additional questions the Committee may ask of the witnesses.

The witnesses are now excused, and the hearing is now adjourned.

[Whereupon, at 12:10 p.m., the Committee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Diane Souvaine to questions submitted by Representative Tonko
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Losing Ground: U.S. Competitiveness in Critical Technologies"

Questions for the Record to
Diane Souvaine, PhD
Chair, National Science Board
National Science Foundation

Written Question Submitted by Hon. Paul Tonko to Diane Souvaine:

Dr. Souvaine, does political uncertainty affect the innovation economy we're trying to cultivate? How so?

Answer:

The knowledge gained from discovery research in all disciplines is central to our world-leading innovation ecosystem and ensures that the U.S. is maximally prepared for an unpredictable future. Congress, presidential administrations, and the research community – all working together with common purpose – have made possible 70 years of these discoveries. As with any long-term investment, especially one whose success depends on developing and keeping a highly skilled workforce, uncertainty reduces efficiency and effectiveness. It imposes roadblocks that leads some of our talent to seek careers elsewhere and can lead to those working in government and academia to eschew the bold questions, the big risks that bring the biggest rewards.

More specifically, **budgetary** stability and predictability minimize waste, allow prudent planning, and ensure that NSF is a reliable partner on the global stage, particularly as it pertains to U.S. participation in large international research facilities. Stability and predictability are critical if we want the best return on taxpayer investment and to accelerate our innovation economy in an era where we have more competitors than ever before. If we are unable to plan and execute a long-term, ecosystem-wide research strategy due to uncertainty, the NSB is concerned that science leadership opportunities may be seized by our competitors, harming our national security and economic growth.

Uncertainty may also impact our nation's ability to attract the best S&E talent from around the world. S&E skills are more easily transferable across international borders than many other skills, and we are now in a global bidding war for S&E talent. While our innovation economy has long benefited from an inflow of scientists and engineers from abroad, there is no guarantee that the best and brightest will continue to come here for their education or that they will stay here long-term to work. Data recently published in *Science & Engineering Indicators 2020* indicate that after many years of growth, the number of international STEM students coming to study in the U.S. has declined.

Responses by Dr. Eric Schmidt to questions submitted by Representative Tonko

Responses to Questions for the Record
Dr. Eric Schmidt

U.S. House of Representatives
Committee on Science, Space, and Technology

Hearing on "Losing Ground: U.S. Competitiveness in Critical Technologies"
January 29, 2020

QUESTION: *Dr. Schmidt, your testimony clearly showed the competitive advantages that China holds in the supercomputing and AI spaces. How did China manage to develop these advantages?*

The Chinese government has articulated ambitious strategies for science and technology advancement, and has pursued those strategies, in coordination with China's research institutes and commercial enterprises, in several ways. Overall research and development (R&D) funding in China has seen a 30 times increase since 1991. The state's directive to develop "military-civil fusion" leverages commercial advances for government objectives. In the AI field, the government and leading Chinese tech firms have organized a "national team" of companies to champion AI development. Beijing has undertaken a concerted effort to recruit global experts in science and technology fields and persuade them to conduct their work in China. China also has benefited from both legal and illegal methods of technology transfer, to include the theft of protected information from U.S. companies, universities, and government institutions.

QUESTION: *Dr. Schmidt, does political uncertainty affect the innovation economy we're trying to cultivate? How so?*

At the heart of an innovation economy are well-resourced research institutions that seek the next breakthrough discoveries and inventions. While political divisions have surely hindered progress in some areas, there is widespread, bipartisan support for proposals to inject new energy and resources into our country's research system. There are opportunities for federal R&D investments to advance emerging technologies in a range of scientific fields that will improve American lives and grow the American economy and ensure the security of our nation. If such initiatives can be geared to complement the massive R&D efforts underway in America's world-leading private companies, we would be able to continue to see great promise for the future of American technology innovation.

Questions submitted by Representative Marshall

QUESTION: *Dr. Schmidt, you spoke about U.S. competitiveness on 5G and how we are losing ground to China due to its sponsorship of Huawei and ZTE. However, a critical factor in the race to 5G is whether we have the workforce that can deploy these networks. Recent estimates say we will need about 100,000 more workers to deploy 5G here in the U.S. What else can the government do to promote 5G technologies and ensure that we have a workforce that can deploy these networks?*

Ensuring U.S. competitiveness in 5G will require a cohesive national strategy that enables U.S. telecommunications firms to compete with Huawei. Competitiveness depends upon investment across a wide range of areas, including in R&D, infrastructure, and our workforce. This strategy also will require a national plan for spectrum allocation that expands commercial access beyond current levels. One key thing the government can do now to promote 5G development is to release more mid-band spectrum for 5G commercial use.

In addition, the United States needs to invest in the nation's STEM workforce to successfully develop and implement new technologies like 5G. This will require assessing and potentially investing in the education pipeline to develop our skilled technical workforce. It also requires us to adapt and expand the available training pathways such as reskilling, apprenticeships, and on-the-job training, as well as other partnerships with the private sector.

Responses by Dr. Chaouki Abdallah to questions submitted by Representative Tonko

1. Dr. Abdallah, your testimony spends time talking about the bureaucratic burden on universities. Has it always been this way? What has changed? Is this an efficient way to execute research?

   I believe the bureaucratic burdens have and continue to increase. Some are due to the increasing complexity of the research problems (larger and multi-institutional grants), but others are due to increasingly conflicting and uncoordinated policies between agencies. The Association of American Universities (AAU) has recently provided feedback on this topic in their response to the JASON report and made the following recommendations: standardizing grant formats and bio sketch requirements across agencies; streamlining pre-award solicitations and requirements; encouraging preliminary proposals, concept papers, and white papers, as appropriate, to reduce the amount of effort that goes into writing full proposals; and implementing one unified federal system for report submissions, among others. Similar recommendations also were advanced in "*Reducing Administrative Burden in Federal Research Grants to Universities*" a report from the IBM Center for the Business of Government. There it was clearly shown that the number of regulatory requirements increased from less than 10 to more than 90 in the last 25 years (*Optimizing the Nation's Investment in Academic Research: A New Regulatory Framework for the 21st Century*, The National Academies of Sciences, Engineering and Medicine report, July 2016). While universities are firm believers in the need for regulations, the increasing resources dedicated to such efforts reduce the efficiency and efficacy of the research enterprise.

2. Dr. Abdallah, in addition to institutional burdens, does the relative decrease in federal dollars also affect individual researchers? How?

   Absolutely! The federal dollars serve a multitude of roles. Chief among those is a signal that the nation is committed to investing in particular areas. This serves to attract researchers into those areas and allows them to build their laboratories, support their graduate students, and plan for multi-year efforts to solve complex research problems. That signal also serves as a talent magnet for the nation's best and brightest students and researchers, ensuring the pipeline is teeming with the next generation of high-skill workers. A relative decrease in federal dollars forces researchers to look for funding elsewhere, or to divert their focus towards shorter-term projects.

3. Dr. Abdallah, does political uncertainty affect the innovation economy we're trying to cultivate? How so?

   I believe so. It is important to note that in order to be daring and innovative in research, one must have the certainty and safety of our institutions, regulations, and laws. One of the reasons that university research results in fundamental findings, as opposed to research conducted in industry, is academic researchers are safeguarded against losing access to their laboratories and funding if their current project does not directly and immediately contribute to a financial performance. Political uncertainty ripples through the agencies and funding funnels, and causes researchers and their universities to avoid risk. That uncertainty can also serve as a dangerous deterrent as researchers may choose to avoid certain fields altogether, risking the long-term pipeline of critical talent.

Appendix II

Additional Material for the Record

ARTICLE SUBMITTED BY REPRESENTATIVE SEAN CASTEN

	MARCH 2018	MARCH 2019	% CHANGE	+/-
China	377,070	369,364	-2.04%	-7,706
India	211,703	209,063	-1.25%	-2,640
South Korea	67,326	62,207	-7.60%	-5,119
Saudi Arabia	47,707	39,535	-17.13%	-8,172
Canada	29,750	29,219	-1.78%	-531
Vietnam	31,613	30,684	-2.94%	-929
Taiwan	23,810	23,762	-0.20%	-48
Japan	23,710	22,378	-5.62%	-1,332
Mexico	15,511	14,915	-3.84%	-596
Brazil	24,858	28,110	13.08%	3,252
Nepal	15,564	15,501	-0.40%	-63
Iran	12,292	11,242	-8.54%	-1,050
Nigeria	15,925	15,890	-0.22%	-35
UK	11,112	10,858	-2.29%	-254
Turkey	11,817	10,919	-7.60%	-898
Total	919,768	893,647	-2.84%	-26,121

US visa data shows declining international numbers

monitor.icef.com

2 mins read

Short on time? Here are the highlights:

- *SEVIS data for March 2019 reveals a year-over-year decline of nearly -3% in the number of foreign students with active US study visas*
- *Numbers from 14 of the top 15 sending markets for the US declined between March 2018 and March 2019*
- *This follows a pattern of marginal declines in commencements and total foreign student numbers in the country that we have been observing over the last two years*

The US Department of Homeland Security's Student and Exchange Visitor Information System (SEVIS) is always an interesting window into international enrolment trends in the US – not least for its ability to provide something close to a real-time snapshot of student numbers.

The latest quarterly release of SEVIS data for March 2019 continues a downward trend that we first observed last year. In March 2018, the SEVIS numbers, reflecting active student visa holders at all levels of study in the US, showed a very marginal decrease (-.5%) compared to March 2017. The March 2019 data now reveals a second straight year of declining numbers with a nearly 3% drop in the number of foreign students with active US student visas.

There were just under 1,170,000 foreign students in the US as of March 2019 compared to slightly more than 1,200,000 as of March 2018 (a decrease of -2.7% year over year). This reflects enrolment at all levels of study – including language courses, degrees, community college, vocational, and K–12 – as well as those students who have graduated but remain in the US for Optional Practical Training placements.

The top 15 sending markets for US institutions and schools account for slightly more than three in four foreign enrolments in the country (76%). The following table looks at the number of student visa holders for each of these leading sending markets as of March 2018 and March 2019.

As the table reflects, 14 of the top 15 source markets declined year over year. In most cases, these are marginal decreases, the exceptions being South Korea (which continues its longer-term trend with a drop of nearly -8% this year), Saudi Arabia (which fell off -17% as the teach-out of scholarship students continues), and Iran (where the -9% decline has likely been influenced by the US administration's travel ban and by rising political tensions between the two countries generally).

Brazil stands out as the lone sending market among the top 15 to have increased as of March 2019.

	MARCH 2018	MARCH 2019	% CHANGE	+/-
China	377,070	369,364	-2.04%	-7,706
India	211,703	209,063	-1.25%	-2,640
South Korea	67,326	62,207	-7.60%	-5,119
Saudi Arabia	47,707	39,535	-17.13%	-8,172
Canada	29,750	29,219	-1.78%	-531
Vietnam	31,613	30,684	-2.94%	-929
Taiwan	23,810	23,762	-0.20%	-48
Japan	23,710	22,378	-5.62%	-1,332
Mexico	15,511	14,915	-3.84%	-596
Brazil	24,858	28,110	13.08%	3,252
Nepal	15,564	15,501	-0.40%	-63
Iran	12,292	11,242	-8.54%	-1,050
Nigeria	15,925	15,890	-0.22%	-35
UK	11,112	10,858	-2.29%	-254
Turkey	11,817	10,919	-7.60%	-898
Total	919,768	893,647	-2.84%	-26,121

Active US student visas for students from leading sending countries, March 2018 and March 2019. Source: SEVIS

This latest SEVIS data reinforces a marginal downward trend in foreign enrolments in the US that we have been tracking over the last couple of years. The Institute of International Education's Open Doors report, for example, highlights that, when OPT numbers are factored out, the number of international students on American university and college campuses fell by -1.3% between 2016/17 and 2017/18. This marked the first time there had been a reduction in this top-line value in more than a decade.

Open Doors reports over the last two years, however, have also noted a decreasing trend in terms of foreign student commencements in the US.